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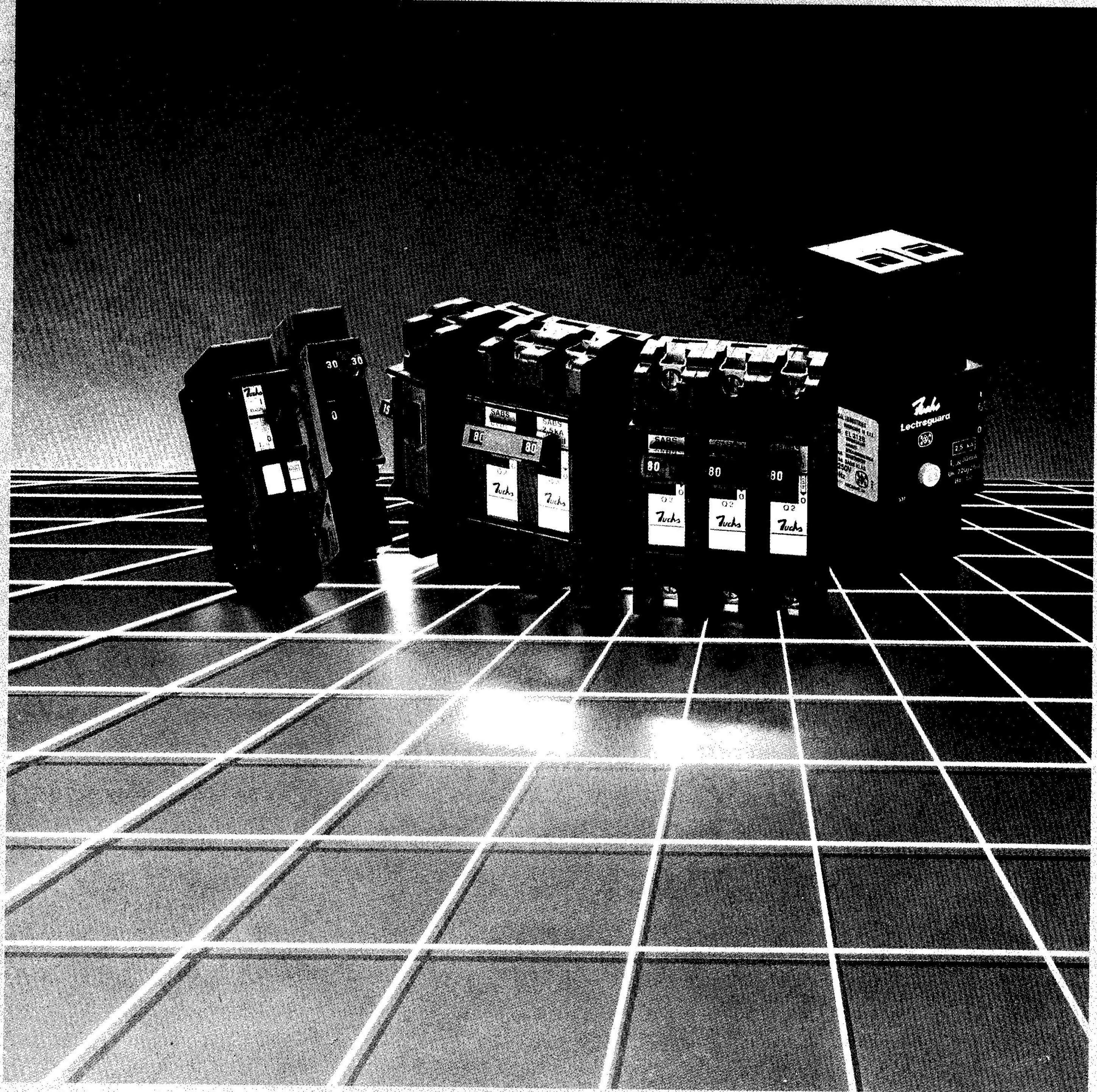
An official Journal of the South African Institute of Electrical Engineers
'n Amptelike Joernaal van die Suid Afrikaanse Instituut van Elektriese Ingenieurs



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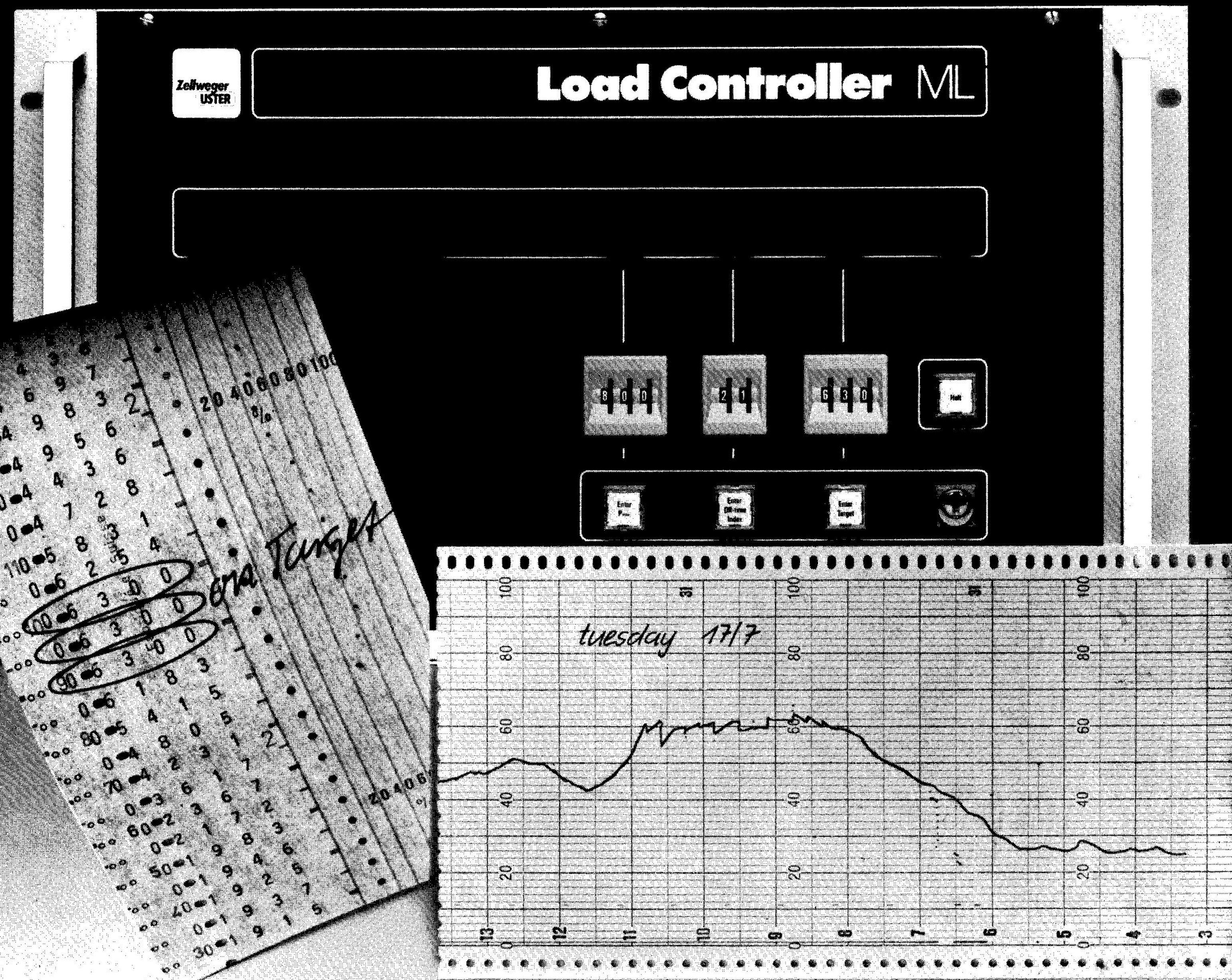

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Comment

The people moving problem in a city is a very real one. In this issue we publish the development by the SA Transport Services of their contribution to the solution but in the final analysis is not this the direct responsibility of the cities themselves.

As a national carrier the network of the SATS should terminate at the outskirts of the cities or at the most in one downtown station and the local authorities or private enterprise operate a co-ordinated service at these points.

Historically the SAR, as it then was, played an essential role in providing rail services for conveying people to and from their workplace, but is it not time that they relinquished this responsibility, which they operate at a loss, and say to Johannesburg and the Reef towns, Cape Town and its satellites, Durban and its townships and others that the mass transport of people within their municipal boundaries is in their court.

There is much talk of privatisation these days — a word not yet in the Oxford dictionary. Is this therefore not an area where private enterprise could play a role and institute a co-ordinated service?

Commuters should be able to buy one ticket to convey them from their home to their destinations whether this be by bus, then train, then bus or any other combination. Only then will we be approaching efficiency and optimisation.

GBJ

COVER STORY

What's in a name?

Fuchs Electrical Industries benefits from the good standing of a name that has enjoyed public esteem for many decades. It was as far back as the 1940s, for instance, that the Alberton Town Council, displaying an opportunistic marketing flair, utilised the reputation of the Fuchs name to draw attention to the industrial potential of the area. 'Fuchs puts Alberton on the Map' it proclaimed in an advertising campaign.

Over the 31 years since its establishment as a licensee to the giant Westinghouse Corporation of the USA, Fuchs has drawn upon — and nurtured with further achievements — the good standing of that name. Internationally, the company is recognised as an innovator, and a leading exponent in the development of the earth leakage industrial and domestic circuit breaker. In 1956, for instance, a coup was achieved by Fuchs with its registration of the first international patent on a magnetic amplifier 20 mA earth leakage device. The company is known in Britain as a supplier of earth leakage equipment and circuit breakers through its agent there, FDB, and it has achieved a successful export record over many years.

Fuch's reputation of course, lies mainly within the borders of South Africa. In the early years of its existence, auto transformers for 110 V compressors were designed and made by the company. Later it started manufacture of current transformers, and, for a period of time, supplied the entire switchgear industry with them. It also manufactured welding equipment, and in 1963 became the first to design and manufacture a 'briefcase' welder that could operate off a 15 A wall plug.

In 1961 Fuchs was largely responsible for the creation of SABS specifications for earth leakage equipment and welding machines. It pioneered the concept and manufacture of the clip-in tray for domestic breakers, pushed up breaker ratings, helped improve SABS circuit breaker specs and effected further improvements on Westinghouse designs.

In the 1970s, the company became the first to introduce solid state controlled circuit breakers in South Africa.

A Fuchs engineer was seconded to Westinghouse in America to assist in the development of the new world beating Westinghouse Series C range, and the company has won three design awards: two Telemecanique awards for the locally developed and designed Motor Sentinel (a motor protection device) and the System Q10, and a Design Institute Shell Design award, also for the Q10.

Forming the nucleus of System Q10 is the single-pole Q10 clip-in type breaker, the design and development of which was precipitated by the electrification of Soweto project.

That application required a 60 A rated single-pole breaker having a 240 V ac, 10 000 A short-circuit rupturing capacity, with selective co-ordinating capabilities. It was specified that the consumer circuit breaker installed in the mini sub or distribution kiosk remain closed, while allowing any electrical fault in the residence to be cleared by the local residential circuit breaker.

The Fuchs breaker satisfied all these requirements, as well as the stringent standards of SABS 156.

A recent achievement has been the design and manufacture of a toggle lock to ensure that NOSA requirements for the protection of service personnel working on electrical installations is met. The breaker can be locked in both the off and the on positions, but because of the unique trip-free mechanism of the Fuchs breaker, locking in the on position will not prevent the breaker from tripping under fault conditions.

The Fuchs range of circuit breakers are of the thermal magnetic type, which ensures virtually instantaneous tripping in response to short-circuit currents, and programmed delay tripping to overload currents. In addition to protection against overload currents, the thermal trip will also provide a back-up to the short-circuit tripping capability of the magnetic protection.

Fuchs also supplies air circuit breakers, which means that rupturing capacities from 2,5 kA to 200 kA, and current ratings from one amp to 4 000 A are covered by the full circuit breaker range.

The company is currently spending R2 million to further develop facilities, and a phased programme for the local manufacture of the complete Series C range will commence in July.

Today, a Barlow Rand subsidiary, Fuchs is the only wholly South African-owned circuit breaker manufacturer in South Africa, and it offers the most comprehensive range of this equipment that is available from any single local supplier.

That's what's in a name!

Further information:
Colin Bower (011) 880-1243/60

The development of electric mass passenger transport in South Africa

J B Quail*
(Assisted by P van Blerk** and T Quirk**)

Historical introduction

'Many shall run to and fro and knowledge shall be increased' *(Daniel 12:4)*

Before the advent of the 'iron horse' in South Africa, for personal transport we had the ox-wagon and the old stage coaches. After these came rickshaws traditionally pulled by Zulus, Cape carts and cabs, horse and mule trams, steam trains and trams, electric trams, buses and electric trains, not necessarily in the order given.

It is recorded that South Africa's first public transport system was a passenger-carrying wagon between Cape Town and Simonstown in 1801. Then came the:

Horse drawn omnibus

1838 Cape Town to Wynberg

Steam trains

1860 Durban-Point-Umgeni

1862 Cape Town-Eersterivier-Stellenbosch

1863 Stellenbosch-Wellington

1890 Johannesburg-Boksburg then extended to Springs and Krugersdorp

1900 Kimberley's 'Puffing Billies'

Horse drawn trams

1863 Cape Town-Greenpoint-Sea Point (Express Cape Town-Sea Point 20 min)

1881 Kimberley Durban and Port Elizabeth

1891 Johannesburg

1897 Pretoria

Electric battery car

1890 Empire Exhibition Kimberley-Beaconsfield

Trolley wire tramways

1893 Crown Reef GMC J Hubert Davies demonstrated one haulage over one mile

1896 Adderley Street-Mowbray with 10 trams built in Philadelphia. Electromagnetic interference problems with communication circuits

1897 Port Elizabeth

1904 Kimberley to Alexandersfontein (6 km price 6 pence)

Electric Railways

It was not until 1909 (the year of inauguration of this Institute) that the real development of electric traction for surface and underground haulage made real progress. The most ambitious project was that undertaken on the Crown Mines and the City Deep. These projects were both surface haulages, utilising the standard South African gauge. The ore was handled in hopper wagons of 50 t capacity, and the locomotives were also employed hauling coal and goods in the South African Railways' owned wagons.

3-phase 50 Hz locomotive

Fifty Hz alternating current for electric traction in South Africa is not as new as we thought, since the three locomotives for this project were built in Germany and were supplied at 2 kV three-phase commercial frequency from two overhead trolley wires and the rail. A locomotive consisted of two coupled units each with a 150 hp 2 kV 3-phase motor driving via a single reduction gear to a jack shaft with cranks, and via two side rods coupled to the four wheels. This mechanical drive proved to be most unsatisfactory and electric locomotives were soon replaced by second-hand steam locomotives ex-South African Railways. This is one of the earliest records known of 3-phase 50 Hz motored locomotives.

This resulted in a setback to the adoption of electric traction by mining properties for heavier work, the failure being mainly due to the faulty construction of this type of locomotive.

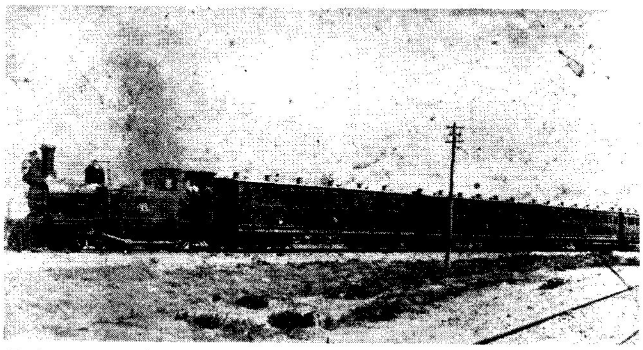
First railway suburban services

The first commercial electrified railway in South Africa was introduced into service in 1925 when electrification of the Natal main line between Glencoe and Pietermaritzburg was completed. This was one of the earliest 3 000 V dc traction systems in the world and used several unique features such as regenerative braking and which can still be considered to have introduced technology in advance of its time.

The first electric suburban service started later and in fact ran between the Monument Station in Cape Town Docks and Sea Point on 17 October 1927. The following year, 1928, the service was extended from Cape Town station to Simonstown.

Unfortunately the Monument-Sea Point line was not a commercial success. High electricity costs were quoted at the time as a major contributing factor and the line was closed in 1929. On the other hand, after some initial financial reservations, the Cape Town-Simonstown electrification became more and more popular with commuters and is still so 57 years later.

The history of railway electrification is very closely linked with power generation and supply in South Africa. The Colenso power



Early steam train

Kimberley's 'Puffing Billies'.

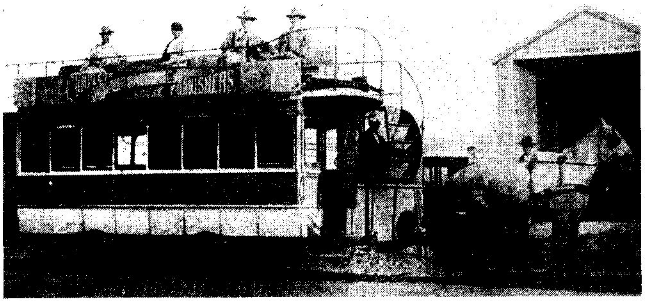
*Chief Electrical Engineer SA Transport Services
** Electrical Engineers SA Transport Services

Note: Historical introduction abbreviated — Editor

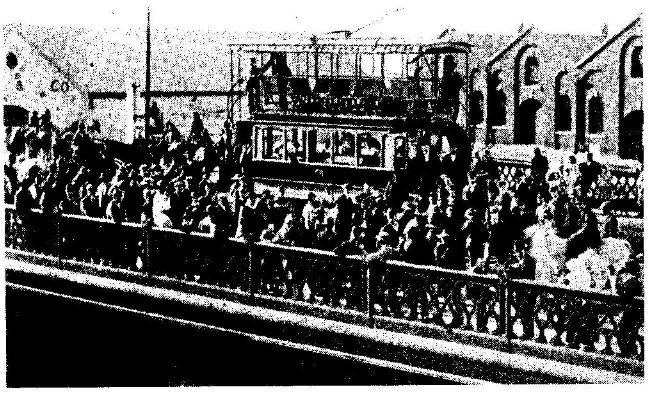
station in Natal was built for the Railways and subsequently became Escom's first power station. The Cape Suburban electrification initiated another Escom power station at Salt River. In fact, a report in 1928 indicates that at that time 80 per cent of Escom's power generation from both these stations was for electric traction.

Some interesting technical details of this first suburban electrification are given below:

- ***By 1928 there were 104 single track kilometres of overhead equipment.***
- ***Six 2 000 kW rotary converter substations were provided by Escom where voltage was transformed from either 33 kV or 12 kV to 1,1 kV ac and then converted to 1 500 V dc.***
- ***The original class 1M1 train sets consisted of six coaches including two motor coaches and were multiple unit stock (EMUs).***
- ***Coaches were all wooden bodies on steel underframes.***
- ***Motors were rated at 700 V with two motors permanently in series each of 138 kW.***
- ***Acceleration was by means of nine resistance notches advanced automatically by a cam-type motor controller released by a current limit relay as current decreased below a set level.***
- ***The four motors of each motor coach could be grouped either in full series or in two parallel groups.***

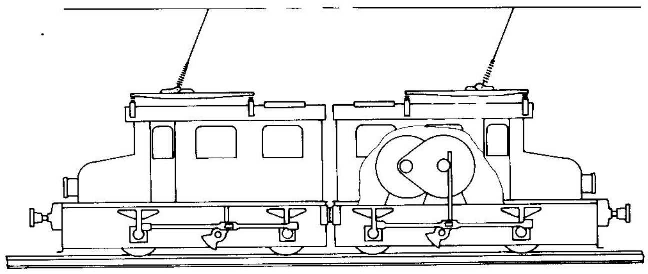


Horse drawn tram.

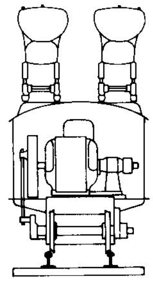


Port Elizabeth electric tram.

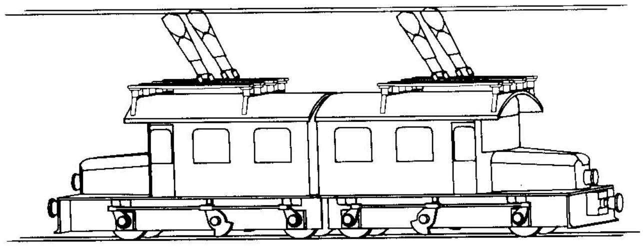
Kimberley and Alexandersfontein tram.



Double unit electric locomotive (1910) 2 x 150 hp, 3-phase, 2 000 V, 50 cps motors.



Isometric drawing of illustration shown below.

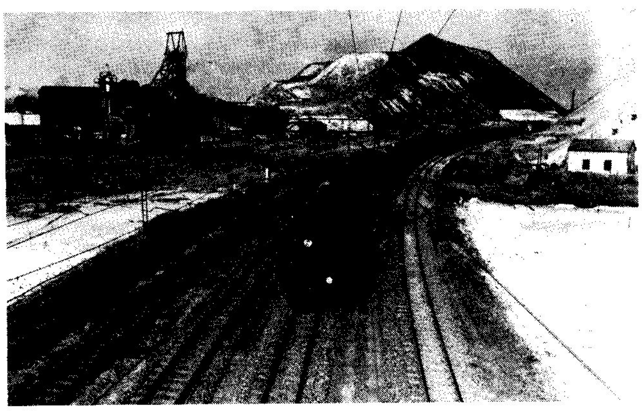


- ***Current collection was by pantograph, two being provided for each motor coach and the collectors were designed for the maximum service speed of 100 km/h.***
- ***In 1933 there were 83 motor coaches with associated trailer coaches and the service handled 26 million passenger journeys per year.***

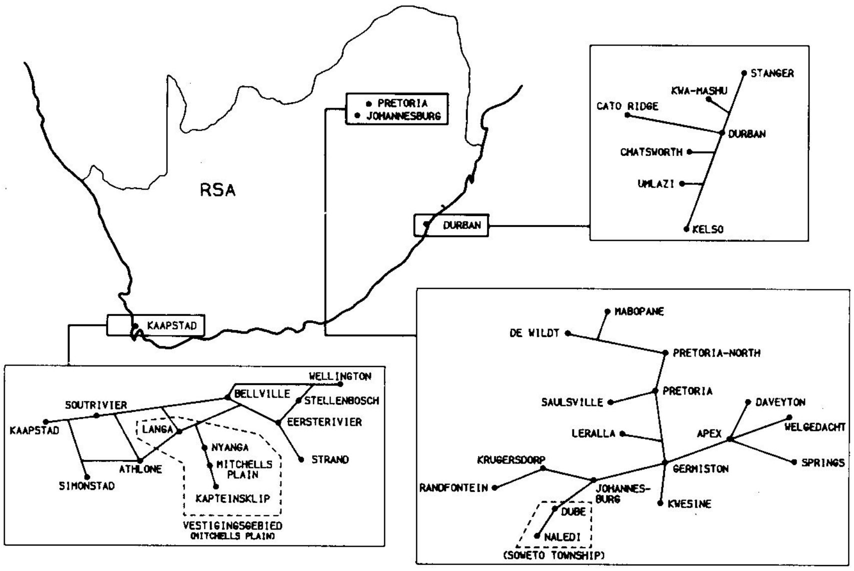
When 1 500 V dc which was the usual standard of the time for suburban systems was adopted in the Cape, no one conceived that the 3 000 V dc main line system in Natal might one day be extended to the Cape. However, when the main line from Cape Town to Touws River was electrified over steep 25 per mil gradients in 1955, there was little alternative but to adopt 3 000 V and to convert the original Cape system.

Early Reef electric suburban train

After preliminary work and careful planning this major change over was in fact effected during one weekend with new mercury arc rectifier substations replacing the old rotary converters and new 3 000 V motor coach stock replacing the old class 1M type.



2MI set at Geldenhuys.



Basic suburban commuter routes.

Suburban electrification took another major step in 1937 when electrification of the first two Reef suburban sections, Germiston-Wattles and Germiston-Alberton were completed, and early in 1938 the full electric service was put into operation between Randfontein and Springs. Introduction of electric passenger services between Johannesburg and Pretoria came later in the same year.

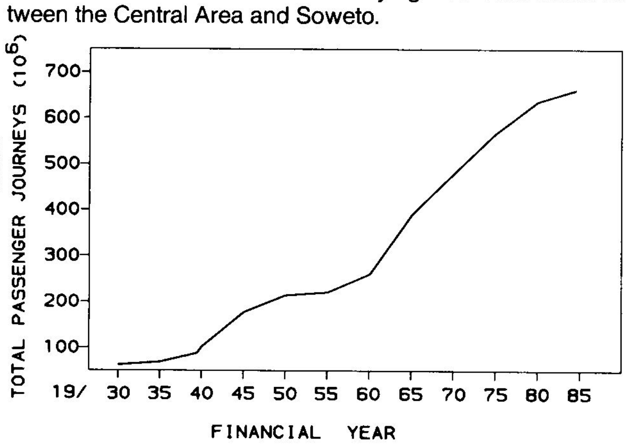
1938 also saw the first third class electric trains introduced into what is now Soweto terminating at Pimville, a line since closed and replaced by a major commuter line.

The Reef electrification system followed the pattern of the original Natal electrification using 3 000 V dc supplied by mercury arc rectifiers which voltage was to become the sole South African standard until 1976.

Present-day commuter services

From the first electric suburban service in the Cape, commuter services have grown in South Africa from the original 104 to about 2 500 single track kilometres in commuter operation.

The heaviest mass transport commuter service today is located on the Witwatersrand conveying most commuters between the Central Area and Soweto.



Growth of suburban passenger services.

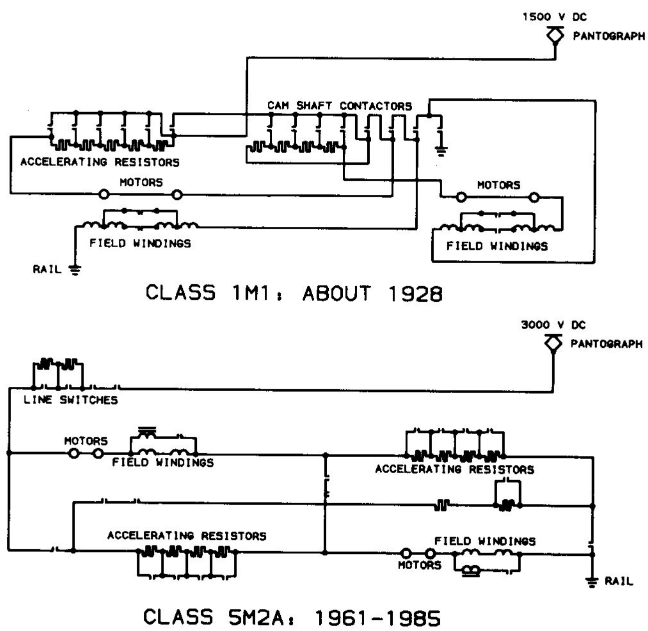
Today Johannesburg station alone handles 561 passenger trains per day and 285 000 passengers. During peak hours trains arrive and depart at 3 min intervals.

South African Transport Services Republic-wide operates over 2 million commuter passenger journeys each working day which is equivalent to moving the entire population of our largest city, Johannesburg, daily. This mass transport is effected at the remarkably efficient energy consumption of 1,2 kWh per passenger journey, which compares with about half a litre of fuel for a diesel bus.

The present electric suburban fleet consists of 1 308 motor coaches and 3 353 trailer cars mainly of type 5M2/5M2A. The number of coaches per train set is either 8, 11 or 14 with the number of motor coaches 2, 3 or 4 respectively. Each standard motor coach of this class has four motors, the rated power output of each coach being 880 kW full field at 1 450 kV. Maximum speed is 100 km/h.

The mass of each motor coach is 62 t, and of each trailer coach 31 t. With maximum crush loading 3 850 passengers can be transported in each 14-coach train. Acceleration in normal service is 0,44 m/s². Deceleration with vacuum braking is 0,7 m/s².

From latest standards the stock is heavy, passenger capacity is limited, especially in the motor coaches due to the large HV compartments, and acceleration and deceleration is low. Also due to unsynchronised notching in acceleration steps and slackness in the conventional couplings, some jerking is inevitable.



Basic circuit diagrams.

Technological improvements which have taken place over the years between the original Class 1M1 stock through five intermediate classes to the current standard are briefly as follows:

- All steel sliding door stock began to replace wooden coaches with swing doors in 1958.
- Number of coaches per train increased from 6 to 14.
- Power increased from 1,1 MW to 3,5 MW.
- Electronic notching relays replaced current limit relays in 1968.
- Electronic voltage regulators replaced electromechanical devices.
- Electro-pneumatic control of equipment replaced electromagnetic and vacuum.
- Automatic pantograph lowering in case of faults. (These motor coaches have no main circuit breakers.)
- Composition brake blocks in place of cast iron.

However, the basic system of resistance control with a number of notches, and combination switching of motors in either full series or series-parallel groups with weak field control for higher speeds was hardly changed over 60 years.

The original camshaft controller of the class 1M1 with nine resistance notches changed to an interlocked relay controlled system with a similar number of individual resistance switches.

In 1973 at a time when thyristor (chopper) control of 1 500 V and lower voltage stock was becoming usual, first two prototypes and later 24 new motor coaches were introduced into service with stepless thyristor control. In all other respects these had to match the existing type of equipment.

Unfortunately in retrospect this technology seems to have been too early for a 3 000 V dc system and the specified requirement of matching existing resistance controlled equipment was too severe for success. South African Transport Services therefore reverted to resistance control for motor coaches until the present day.

The introduction of power electronics which has been so successful with South Africa's latest ac electric locomotives has therefore had to wait for a new generation in order to be applied to electric mass passenger transport.

Class 6M suburban train.

The new generation

The necessity to increase passenger-carrying capacity, the fact that the advance of modern cost-effective technology has now exposed the weaker features of standard stock together with increasing costs of energy led to the decision of SATS to introduce a new generation of commuter passenger train specifically designed for the Soweto and similar mass transport services. Two prototypes, Class 6M and 7M of this new generation have now been supplied and the 6M is already in regular service. These will be used not only to evaluate the trains themselves but also the systems and subsystems most suited to South Africa's suburban network conditions.

The first of the two trains delivered is known as the class 6M train. It was imported from Japan and is made up of four modules. Each module is a self-contained consist, comprising three vehicles semi-permanently coupled to each other. Two of these vehicles are motorised and contain eight 245 kW series wound dc motors.

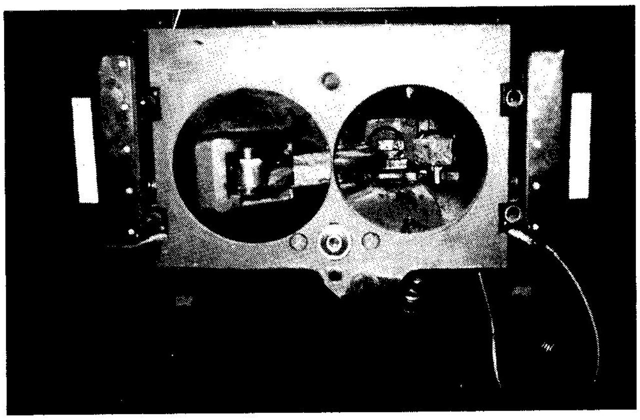
The second train delivered came from Germany and is known as the class 7M train. It is made up of three modules of four coaches each with half of its axles driven by 290 kW motors. These series connected motors are 80 per cent excited with non-inductive field weakening resistances across the fields.

Class 7M suburban train.

Features of the new generation trains

Both trains are equipped with an automatic type coupler at the ends of each module which couples electrically, mechanically and pneumatically one module to the next.

During off peak periods passenger counts are under 25 per cent of train capacity. This auto-coupler will allow the driver for the first time to readily shorten the trains to accommodate these very low passenger counts and thus save energy. It is also the intention in the future, to run more frequent but shorter trains during the off peak periods to attract clientele.


Class 7M automatic coupler.

Class 6M underfloor equipment

As all the equipment is mounted underfloor to make maximum use of the passenger area it also means that the mass of the equipment is now uniformly distributed such that the individual axles have the same accelerating and braking requirements. Slip and slide will thus be considerably reduced. Nevertheless a 'load weighing' system adjusts the power and braking forces to the load of the train so that acceleration and deceleration rates are not influenced by the number of passengers carried.

This adjustment as well as tight electronic control of slip and slide results in improved slip performance. Suburban trains are relatively light in relation to their available tractive effort and standard sets in particular tend to slip when lightly loaded.

On the sides of the coaches there are train route numbers which are remotely set by the guard. A check back signal informs him of maloperation of any particular unit.

Class 6M interior

Inside a high illumination level is provided and over each door or vestibule area there is an emergency light fed directly from the train's batteries in cases of power failure. A public address is used to inform passengers of forthcoming stations and of unforeseen delays.

Class 6M interior.

Class 6M power circuit

The pantograph feeds power via line breakers to a choke-capacitor filter, which feeds the traction motors with their associated fields and controlling thyristor choppers.

The motors of both new generation trains are controlled by choppers. The advantages over the conventional resistance control are:

- energy savings during starting and stopping. These savings are sizeable in a suburban service with many starts and stops. The chopper also reduces the current peaks that are required so the costs of providing the power supply and transmission systems are minimised.
- the chopper provides smooth and continuous control of traction motor voltages. This reduces jerking, slipping and sliding.
- maintenance costs are lower because of the use of static devices and temperatures are lower. Also under normal operating conditions switches are only opened once the currents have been reduced to zero.

A further advantage is in the electronic protection in that the chopper can be blocked in 3,36 ms.

Class 6M automatic field weakening system

The 6M is equipped with an automatic field weaking system. This automatically varies the weak field ratio by changing the conduction ratio of the chopper. It is accomplished by splitting the series field of the traction motor into two. One portion is in series with the armature. The other is in the interrupted current circuit in series with the freewheeling diode.

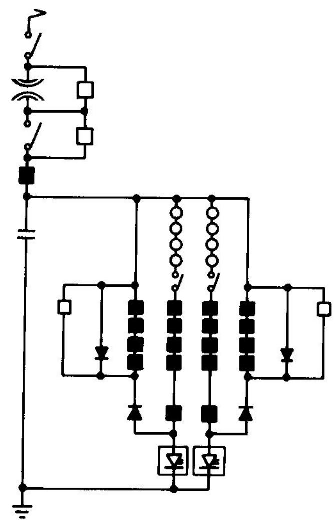
At low speeds the conduction ratio is small. Major part of the time the chopper is off and the current flows via the free-wheeling diode through the automatic variable field. Therefore at low speeds a substantially full field motor results. At high speeds the conduction ratio is greatest and only the field in series with the armature is effective.

Compared with some other countries South Africa has relatively long interstation distances and the increased performance at high speeds is of greater value. Other advantages of the system are that field weakening is achieved without an additional field weakening chopper or field shunting contactors.

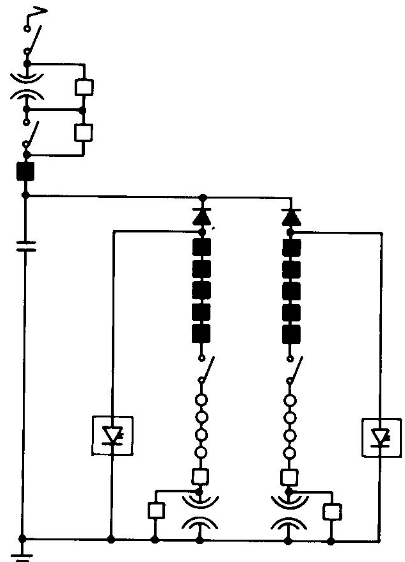
Class 6M simplified schematic of chopper

The actual chopper circuit of both trains is very similar and uses a series commutation method for commutating the main thyristors. The turn of thyristors once fired start a series L-C oscillation which reverses the polarity across the main thyristors thus turning them off. Reverse conducting thyristors (RCTs) are used throughout.

An interesting feature of the 6M is a fibre optic transmission system which operates a target type relay when a device fails.

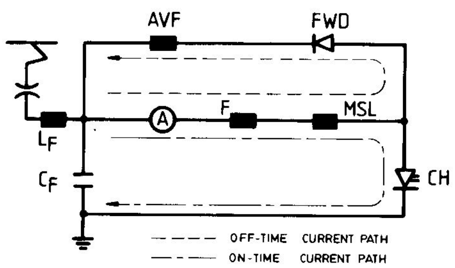


(a) 6M Powering mode.

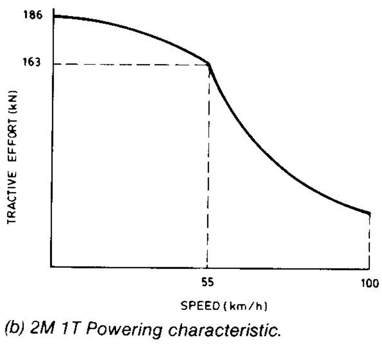


(b) 6M Braking mode.

Class 6M power circuit.

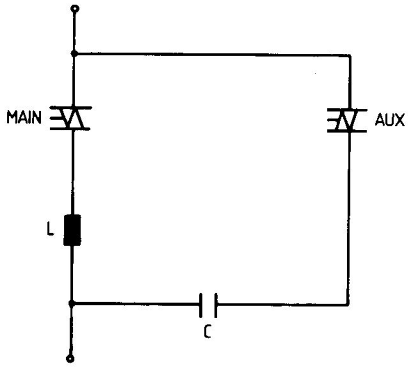


(a) Simplified schematic powering.



(b) 2M 1T Powering characteristic.

Class 6M automatic field weaking system.

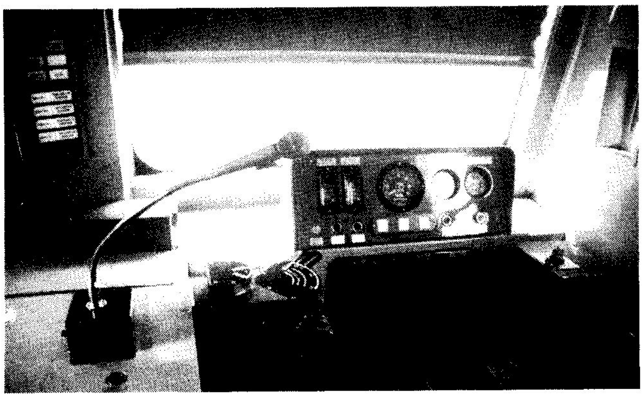


Class 6M simplified schematic of chopper.

Class 6M driver's compartment

A somewhat unique deadman system was developed on the 6M train. Normal procedures of constantly depressing, gripping or twisting a handle were felt inadequate as they can too easily be nullified.

A means was therefore sought whereby the driver would be required to make a positive 'resetting' action on a particular command. On these trains whenever the accelerating handle is moved to the 'off' position in preparation to either coast or brake a buzzer sounds. Failure by the driver to reset the deadman within two seconds of this buzzer results in an emergency brake application.



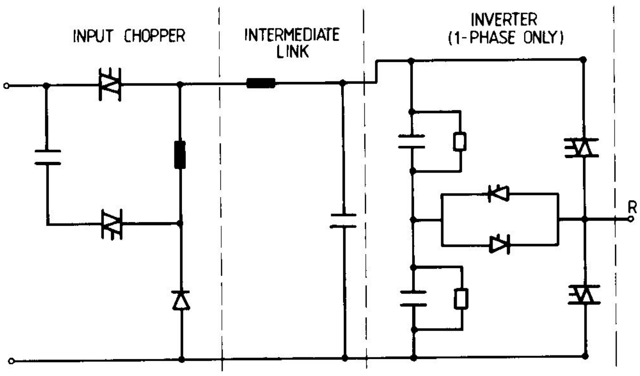
Class 6M driver's compartment.

Class 7M static invertor schematic

The 7M train is equipped with a thyristor-controlled auxiliary power supply system. This static invertor performs the power conversion to 380 V 3-phase in two stages.

Firstly a chopper circuit similar to that of the main armature chopper converts the overhead 3 kV dc supply to a constant dc voltage of an intermediate link. The pulsating output voltage of the chopper is then converted by a choke and capacitor into a dc voltage of low residual ripple.

The second stage is an invertor consisting of three identical modules each containing two reverse conducting thyristors. It produces 380 V, 3-phase, square wave, voltage.



Class 7M static inverter schematic.

Class 7M microprocessor

A microprocessor-based control system supervises the control and protective functions of the 7M.

These functions include:

- wheel slip/slide detection and correction.
- jerk limitation in both the accelerating and braking modes.
- traction motor current and torque control.
- pulse generation for firing of the power thyristors.

All fast and regulation functions such as the regulation of the armature currents are repeated approximately every 1 ms. Functions requiring less frequent monitorings are processed every 15 ms.

Integrated with this control system is a fault monitoring system. This dictates the reaction of the train to a fault condition. Failures are categorised by the monitoring system and the memory stores a substantial list of conditions. This list contains all input and output signals as well as logic monitorings. This system will considerably simplify trouble shooting. Other advantages of the system are:

- a low component count. This affects cost and reliability.
- digital processing means that temperature and ageing effects normally associated with analogue electronics are minimised.
- parameters can readily be altered during commissioning and evaluation periods.

Testing

The testing programme to date has involved only the class 6M train and all results quoted for the new generation trains are for that train only. Initially a base data test was performed in which various currents, voltages, speed and brake cylinder pressures were measured. These recordings were very interesting and demonstrated features of the power circuit such as:

- the transformer action between the motor voltages and line currents.
- jerk control at slip/slide conditions.
- the field weakening effect of the automatic variable field control.
- frequency changing at starting and
- blending of the regenerative and pneumatic brakes.

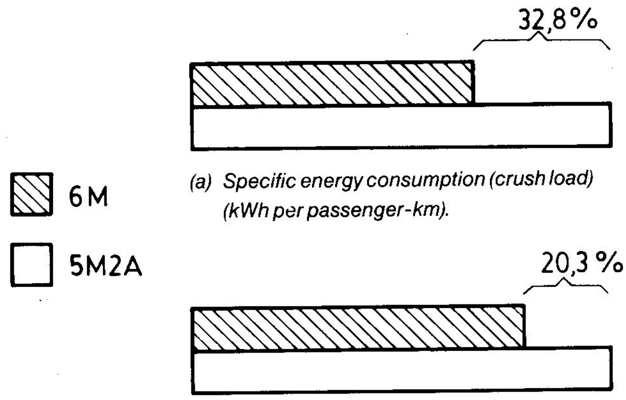
Acceleration tests conducted showed that average acceleration of 0,83 m/s/s or 3 km/h/s to 50 km/h which is better than the declared values. The top service speed of both trains is 100 km/h and they rely on high acceleration and deceleration rates to attain this on a suburban service with short interstation distances and many starts and stops. High top speeds are really only for intercity trains. Deceleration tests gave a rate of 0,9 m/s/s.

The 6M was specifically designed for Soweto and consequently for all loading conditions and all sections of track in Soweto the energy consumption and running times were measured. Regenerated energy ratios of between 30 per cent and 36 per cent were recorded. However for convenience of testing the section Mayfair to Randfontein was chosen. This section has a better availability and with an interstation distance of 1,6 km is typical of Soweto sections.

Specific energy consumption

The conventional 5M2A train and the 6M were loaded in accordance with new generation specifications which are:

normal load seated + 6 per m² standing and
crush load seated + 9 per m² standing.
The tests revealed an improvement in crush loaded specific energy consumption (Wh per passenger - km) of 32,8 per cent. The actual figure for the 6M is 8,6 Wh per passenger - km. An improvement in timetable times of 20,3 per cent is possible.



(a) Specific energy consumption (crush load) (kWh per passenger-km).

(b) Timetable times.

Performance comparison

Headways between trains are determined by the train performance. Should only class 6M trains run in the section then 23 class 6M trains can run in the place of the present 20 class 5M2A trains per hour. This means that with the new trains 19 000 additional passengers will reach their destinations and they will have spent 13 min less time on the train. Furthermore the 23 class 6M trains will have consumed 6,4 MWh less energy than the 20 class 5M2A trains.

Comparison of energy consumptions

Test Line: Mayfair to Randfontein (80 km return, 52 stations).
Service Duty Cycle: (6 tare + 12 normal + 12 crush) trips per week for a 50 week year.

	5M2A	6M
Train Formation*	4M 10T	8M 4T
Service Duty Cycle Nett kWh/week	109 566	78 450
Nett kWh/year	5 478 300	3 922 500
Nett kWh/40 years	219 132 000	156 900 000
Nett cost/week	R4 500	R3 215
Nett cost/year	R225 000	R160 750
Nett cost/40 years	R9,0 M	R6,43 M
Energy saving per train compared to 5M2 A		28,4 %

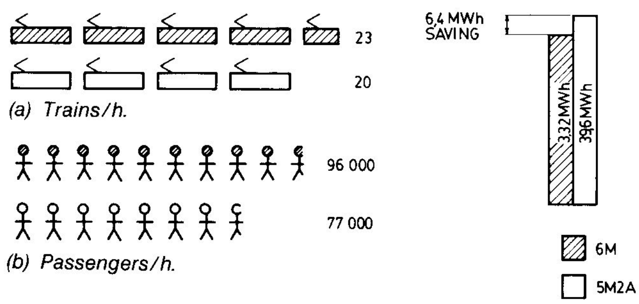
*M - Motorised car
T - Trailer car

Energy cost savings

Calculations of nett energy consumed for a 6M and a 5M2A running on the Mayfair to Randfontein section for 50 weeks per year were compared. A service duty cycle of a typical week was taken as 6 tare, plus 12 normal, plus 12 crush load trips. It was shown that over the expected life of one train (ie, forty years) energy savings with the 6M will be over R2,5 M.

The last tests the author will comment upon are the short circuit tests. At speeds between 20 and 80 km/h in both powering and braking an external earth was applied to the overhead line. This was achieved using a spring loaded knife switch connected across the earthing switch of an energised locomotive. This knife switch was held open with an electromagnet. Radio communication ensured that the electromagnet was de-energised ie, the short circuit was applied at a time of maximum current.

Under these conditions the chopper must totally block and the train's line breakers must operate. Although there was severe jerking at no time did the currents reach levels at which flashover of the traction motors could result. Nevertheless the motors were periodically checked but showed no sign of flashover whatsoever.



(c) Nett energy consumption.

Conclusion

Mass transport in South Africa has gone through many phases and in general today is mainly provided by electric suburban type trains, standard buses and increasingly by minibuses. South African cities for their own reasons and contrary to most Continental and American cities, have never introduced Light Rail Transit Systems (which are in fact modern trams) or Metros. (Mainly underground electric commuter systems.)

It is not the purpose of this paper to predict which way mass transport will develop, but the two obvious alternatives are either that multi-lane road systems must be provided for large numbers of buses or one of the electric rail systems must be adopted.

The new generation now being introduced by the SA Transport Services can well be a prototype for future rail systems. However, the advance of technology will certainly not stop here, and already cost reductions in power electronics are starting to make the introduction of variable frequency three-phase traction motors with convertors an economic possibility.

Perhaps the failure of South Africa's first three-phase motored locomotive in the early 1900s may yet be offset by the success of this technology in the future.

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Energy and ecology

All forms of energy derived from nuclear and fossil fuels produce pollutants as a by-product. Some of the products such as petroleum and diesel oil again are the source of pollution when burned in internal combustion engines.

Thus it is that we have at last been awakened to the threat that these emissions from chimney stacks and exhaust pipes have reached such proportions that when dissolved by moisture in the atmosphere and precipitated by rain are a danger to our priceless heritage of forests and fields.

The country which appears to be most advanced in the awareness of this situation is the Federal Republic of Germany. The table below gives some indication of the estimated quantities of dust and gases emitted over their country in 1978.

	Dust	C_mH_n	NO_x	So_2	CO
Pollutants tonnes x 10^6	0,7	1,8	3,0	3,5	9,3
Power Stations	24%	—	31%	56%	—
Industry	64%	27%	19%	28%	15%
Household and small businesses	—	35%	5%	13%	18%
Transport	8%	37%	45%	3%	67%
Miscellaneous	4%	1%	—	—	—

(Source: Siemens Review)

Coal fired power stations were responsible, as will be seen, for producing 2,1 million tons of SO_2, while transport was the chief culprit for the C_mH_n chain, the nitrous oxides and the carbon monoxide resulting in a total of 8,25 million tons of these gases.

In 1974 the Federal Republic of Germany was aware of the rapidly advancing threat and made flue gas desulphurisation of all new stations compulsory and in 1983 amended the ordinance to introduce a 15 000 million DM programme up to 1988 to retrofit desulphurisation plants to existing power stations.

The world today has an apparent insatiable appetite for coal. In South Africa alone our export target through Richards Bay is ±67 million tons for 1985. By the year 2025 it has been calculated for instance, that the demand for coal will be three times the present consumption. The question therefore of atmospheric pollution and its effects on our ecology must be answered now. Procrastination will indeed be the thief if we delay.

Although we in South Africa do not perhaps compare with the highly concentrated industrial areas of Western Europe, we nevertheless are slowly awakening to the 'acid rain' threat. On the Witwatersrand we complain bitterly about the drift of H_2S across our cities because of its offensive odour but forget about the insidious effects of other pollutants.

The question is: do we treat the cause or the effect. The answer is surely treat the effect as a short-term measure but have an active programme to solve the cause. For instance why is it that to produce a ton of steel Japan, Italy and Spain use only half the energy as do China and India. The Soviet Union and France use two-thirds as much as Canada. I have not been able to get our comparative figures.

But it is not only the sulphur dioxides that we must concentrate on. The IC engine with its inefficient fuel burning and with the increasing *per capita* vehicle ownership in South Africa is perhaps just as great a threat.

The article below details certain investigations being undertaken in the UK in order to determine facts and figures on which to base research. There is no question that short-term solutions such as desulphurisation plants and platinum catalysts must be introduced but at the same time the causes must be remedied.

GBJ

Combating acid rain

Eric Ford,* *BSc (Econ), BComm*

The misleadingly simple term 'acid rain' is usually used to refer to the complex problem of acid deposition and its effects on the environment. Natural processes have always provided some deposit of acidity, but today most of this phenomenon is caused by the combustion products of fossil fuels.

Deposition takes place not only in wet forms, through rain, mist and snow, but in dry forms through gases and minute particles.

It is generally agreed to affect water bodies, vegetation and buildings. Effects on lakes and forests, in particular, are matters of considerable political concern in many countries, and international pressure is mounting for remedial action, even though scientific agreement about the most effective remedies has yet to be achieved.

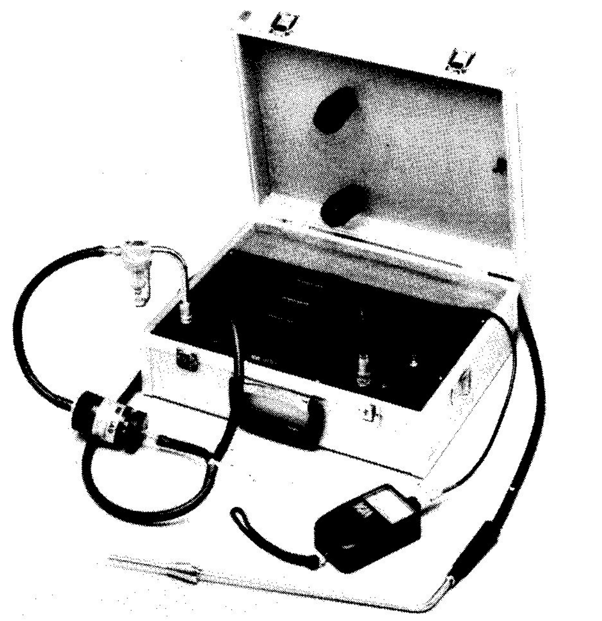
Few people doubt that acid rain is harmful, but the degree of damage, and the relative roles of deposited acidity, direct toxicity of atmospheric pollutants and the slow natural processes in soils and aquatic systems all remain uncertain. What is generally agreed is that unbiased, independent research is required, and this will be expensive.

Britain's Royal Society is closely involved in the investigation of acid rain, its causes and effect, and has recently undertaken to manage a new study of the subject, with participation of corresponding societies in Norway and Sweden. Britain's Central Electricity Generating Board (CEGB) and National Coal Board (NCB) are jointly providing R11¼ M to fund this study, but a larger sum — R6 750 000 M a year — is being spent by the Department of the Environment on research into the problem.

Causes not proven

While it is thought that coal fired electricity generating stations are responsible for some 60 to 70 per cent of the sulphur dioxide (SO_2) deposits, both the CEGB and the NCB claim that the precise causes of acid rain are not clearly proven. They warn that precipitate action, at high cost, could fail to solve the problem since it is also widely accepted that chemical plants and cars — the latter producing enormous amounts of oxides of nitrogen — contribute to the causes.

The CEGB, jointly with Britain's Meteorological Office, is carrying out fundamental research which includes its so-called 'flying programme'. This involves the use of highly instrumented aircraft which fly forwards and backwards at right angles to the plumes of smoke emitted by coal fired power



Combustion analysers, used to adjust boiler or furnace controls to ensure optimum combustion conditions, can also reduce the emission of pollutants.

*Editor, 'Engineering Gazette', London.

stations. The results of this programme, on which R11¼M has been spent in the past five years, is revealing the transformation into acid rain of the sulphur and nitrogen components in the air.

Electricity generating stations are not the only users of coal, but their coal consumption represents about 70 per cent of the total. There can be no short-term prospect of using alternative fuels for power generation, as natural gas is not an economic proposition and nuclear power is only slowly replacing coal and oil in the production of electricity.

Principal fuel

Since coal is to remain the principal fuel for power generation, new ways of burning it must be considered. And sulphur emissions from the use of coal by industry also have to be taken into consideration.

There are three ways of approaching the problem: before, during or after combustion. Pollution can be attacked at the point of generation — that is, by redesign of coal burning plant — or by new methods of combustion. Alternatively, the pollutants can be controlled, after combustion, by treating the flue gases.

The Energyman microprocessor-based system for boiler management provides continuous monitoring of boiler combustion efficiency, as an aid to better control of emissions of flue products to the atmosphere.

One of the most promising approaches is fluidised, bed combustion. By this method a solid bed of suitable fine material, usually sand, is subjected to a flow of air which has the effect of causing it to act like a liquid (hence the term 'fluidised bed'). Pollution is reduced partly because coal is burned in this bed at higher efficiencies than in a conventional boiler or furnace, so that a wider range of fuels can be consumed, including waste derived types. The important point, however, is that the sulphur content of the flue gases can be greatly reduced by adding limestone or dolomite to the bed material.

Furthermore, the lower temperatures at which fluidised bed furnaces operate reduce emissions of the other element in acid rain — oxides of nitrogen.

Fluid bed combustion

Following research and development by the NCB, fluidised bed equipment is now available from a number of British manufacturers. They include the Energy Equipment Company which offers complete turnkey projects based on this technology.

In one example of a boiler fired by fluidised bed principles, savings of around R675 000 a year are expected. The same company also supplies fluidised bed drying machines, generating a stream of hot air up to 1 350 °C for grass drying and other applications.

These are fairly large appliances. More recently, the firm has developed a smaller unit. Known as the Finafire, it operates in the range of 1 to 15 t/h steam raising capacity. It is designed for hospitals and similar uses.

Remedial measures

Whatever steps are taken to reduce pollutants at source, some unwanted gases and particulate matter will be discharged from furnace flues. Remedial measures are therefore needed to combat the pollutants in the stack, before they can reach the atmosphere.

Principal methods under development include the well established wet scrubbing, which increases the mass of particles and fumes in the gas stream for easier removal by gravity or centrifugal separation.

Work in this field is concentrated on reducing the energy required by the fans needed to overcome pressure losses, and by the pumps that form an important part of the process.

Electrostatic precipitation, which can control particles down to sub-micrometre size, is regarded as a versatile system.

British companies which use this technique in their range of products include Lodge Cottrell. Its equipment of this type operates over a wide range of inlet conditions, such as temperature, pressure and dust burden, collecting both wet and dry dust.

Electrostatic precipitation combines high efficiency with low operational costs. For example, pressure loss across the precipitator is almost negligible so that minimal fan power needed, so economising in the use of electricity.

More recent methods of removing sulphur dioxide from power station and other emissions is spray drying, which, it is estimated, can remove over 90 per cent of the sulphur from the stack discharge. It has now been found that the same process can simultaneously remove up to 50 per cent of the nitrogen oxide emissions.

Assessing the problem

Before remedial measures can be planned and applied and, indeed, in order to decide the precise source of pollutants, it is essential to have means for accurate measurement of the type and extent of concentrations.

Measurement is necessary at various points. Measurements made inside the flue or stack of boilers and furnaces indicate the proportions in which the various gases are present.

Measurement of stack constituents is increasingly used as a means of checking the efficiency of the combustion system. This requires measurement of oxygen content, carbon monoxide, carbon dioxide and temperature, but the system can also be applied to sulphur emissions.

More usually, however, measurements are made outside the stack, to check the effectiveness of the control measures taken.

More reliable information

In the view of many British authorities involved in assessing the acid rain problem and those that will incur the cost of remedial measures, the need is for more reliable information on the extent of any British responsibility for the problem.

To this end, work is being carried out by the Warren Spring Laboratory. Its programme of measurements of sulphur emission from all sources is funded by the Department of the Environment, and is based on a number of strategically placed measurement stations throughout the United Kingdom.

This is part of a continuing research programme which will provide accurate information about both the volume of emissions and their direction of movement.

With the current European Community draft directive calling for a reduction of 60 per cent in sulphur emissions, 40 per cent in nitrogen oxides and 40 per cent in particulate emissions, European industries could face heavy costs. Similar demands are likely to be made on other industrialised countries, especially North America.

Britain's contribution towards the measurement and control of factors affecting the deposition of acid rain will therefore arouse keen interest in all countries where this problem is causing increasing concern. ■

Matching+

P W van der Walt*

The maximum power theorem, and the related concept of matched impedances, is one of the first circuit theorems that a student of electrical engineering is taught. Soon after his (and, fortunately, her!) acquaintance with this theorem, the same student quickly finds out that the theorem is hardly if ever applied in practical systems!

In power systems, where megawatts of power are transported all over the place with total disregard for the theorem, load impedances are orders of magnitude larger than the equivalent generator output impedances.

Audio amplifier specifications may state that the amplifier is matched for 8 ohm loudspeakers; the output impedance of such an amplifier is typically of the order of 0,01 ohms (for good damping).

Other examples of mismatched systems abound.

Loads connected to batteries only approach the batteries' output resistance under transient or fault conditions; measurement systems are usually highly mismatched so that very little power is absorbed from the system being measured; impedance levels are seldom of concern in digital systems.

In desperation, the student may look towards high-frequency communications systems. Surely receiving antennas should be matched to their loads? They usually are, but not so much for transfer of power as the elimination of reflections. A price, an increased noise figure and therefore an effective loss of signal power, is often paid for this matching! Controlled mismatch is, in fact, found more often than perfect matching in high frequency systems.

It is only a matter of time before the maximum power transfer theorem is rejected as irrelevant.

Maximum power transfer was controversial from the very beginning of the art of electrical engineering. In the previous century, when carbon arc lighting was in vogue, generators and loads were, in fact, resistance matched. When Edison introduced his incandescent lamps and claimed an efficiency of 90 % for his generators, established engineers scoffed at him [1]. Previous tests by the Smithsonian Institution had shown that generators have efficiencies of less than 40 %, which tied in nicely with the ideal 50 % predicted at maximum power transfer; Edison's claim seemingly violated the power transfer theorem, and therefore had to be wrong.

With hindsight, it is appreciated that the real reason why matched designs were considered necessary, was to obtain good load regulation for the protection of both the generator and the arc light. On the other hand, Edison wanted to maximise efficiency; he disregarded the requirement for maximum power transfer.

Edison must be credited for trying the unthinkable, and thereby laying the foundation for modern constant voltage power distribution systems.

Yet, the maximum power transfer theorem, and the related concept of impedance matching, is one of the most powerful theorems of circuit theory. It is fundamental to the design of passive filters and wideband impedance matching networks. Indirectly, it provides the basis for a class of high performance active RC, switched capacitor and digital filters. It is central to all high frequency electronic design. It is still the subject of active research [2], and lies at the heart of at least one of the unsolved problems in electronic engineering [3].

+Chairman's valedictory address, delivered at the AGM of the Cape Western Centre of the SAIEE on 14 February, 1985.

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Passive filters

With reference to the circuit model of Fig 1, maximum power is delivered to the load R_l when $R_l = R_g$. In Fig 2, loci of constant power is shown in the complex impedance plane for the ac circuit model of Fig 2. These figures show cuts through the three dimensional surface in power-impedance space, relating resistance, reactance and power. A representation of this surface is shown in Fig 3.

In the complex impedance plane, Fig 2, the circles of constant power are bunched near the origin. A bilinear transformation of the co-ordinate system, ie, a projection of these circles on a new deformed, plane, results in the well-known Smith Chart [4], as shown in Fig 4. This chart, devised in 1939, survived the arrival of the computer, and remains one of the most powerful design aids for impedance matching problems with both transmission lines and discrete elements. New applications for the chart, and new insight into its use, are still reported in the literature [5].

A model of a doubly terminated lossless passive filter is shown in Fig 5. As far as the generator is concerned, it drives a load Z_{in}; the power delivered to that load is determined only by the value of Z_{in}. The filter, typically an LC network, is lossless. No power entering the filter can be dissipated by the filters. This leaves only one option: power entering the filter, determined by Z_{in}, and only Z_{in}, must be dissipated in the load.

When Darlington [6] and Cauer [7] proved that all realisable passive impedances can be synthesised as a lossless network terminated in a single resistor, the foundation was laid for the modern theory of filter design. According to this theory, a realisable impedance function must first be found; this impedance must vary with frequency in such a way as to satisfy the power transfer requirements of the filter. Once a suitable

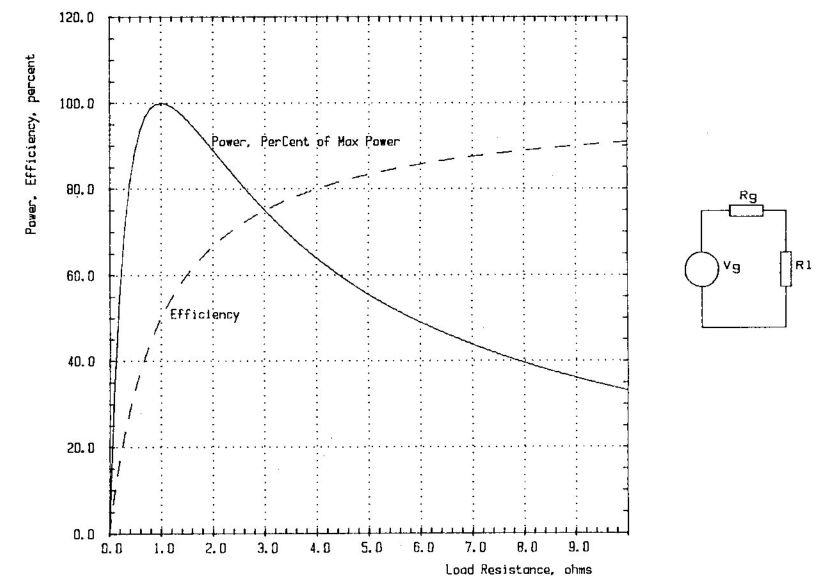


Fig 1 Load power and efficiency as a function of load resistance.

impedance function has been found, standard techniques of network synthesis may be used to synthesise the filter.

In order to relate the impedance function to the required response, it is helpful to think in terms of available and reflected power. The generator always delivers all of its available power. The load impedance either absorbs or reflects power, the sum of absorbed and reflected power always equalling available power. The required filter function, the transducer factor, defines the ratio of available power to absorbed power. As long as this function is in the form of an even rational fraction with a magnitude larger than one at all frequencies, it is a realisable

IMPEDANCE OR ADMITTANCE COORDINATES

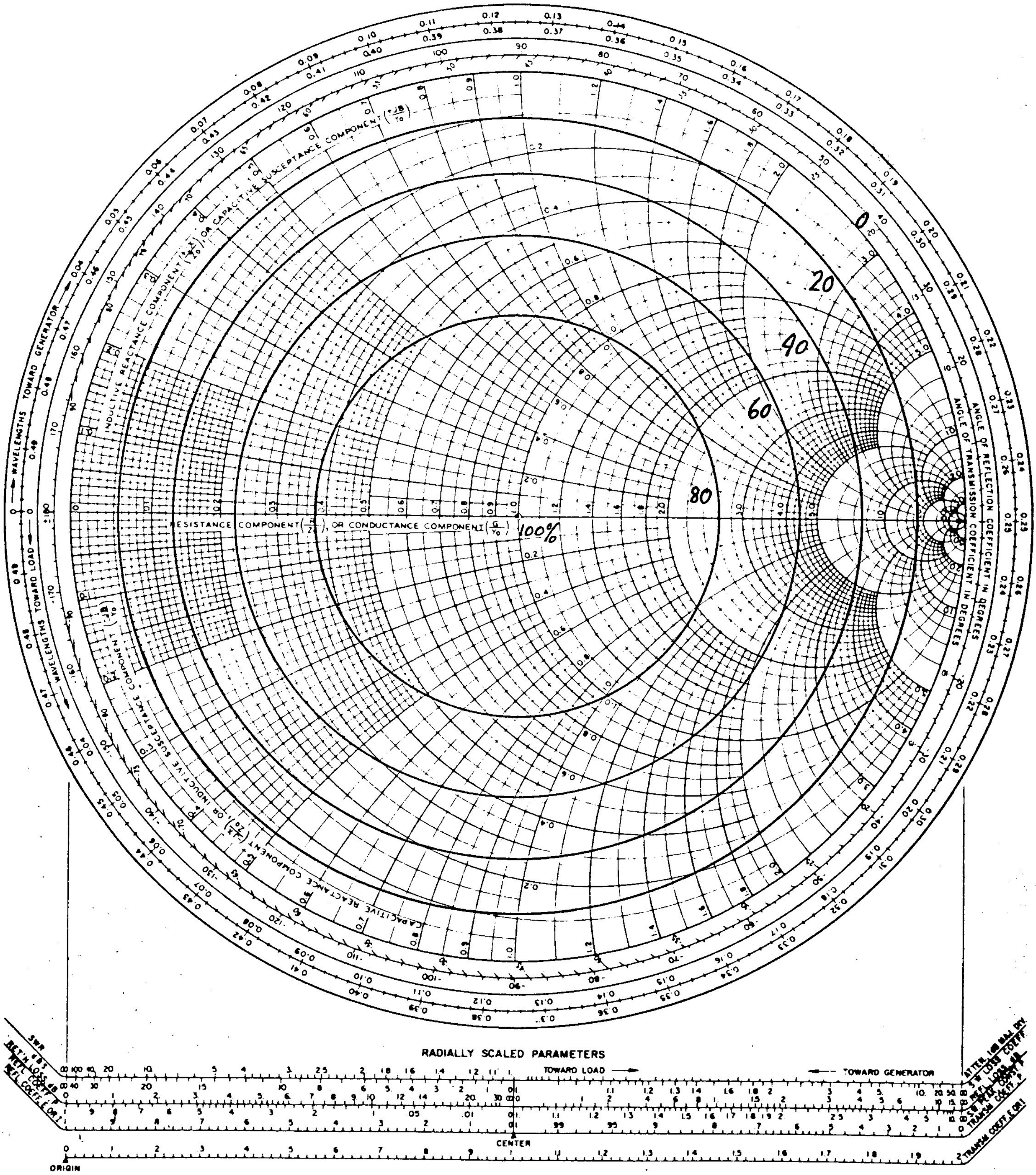


Fig 4 Circles of constant power on a Smith chart.

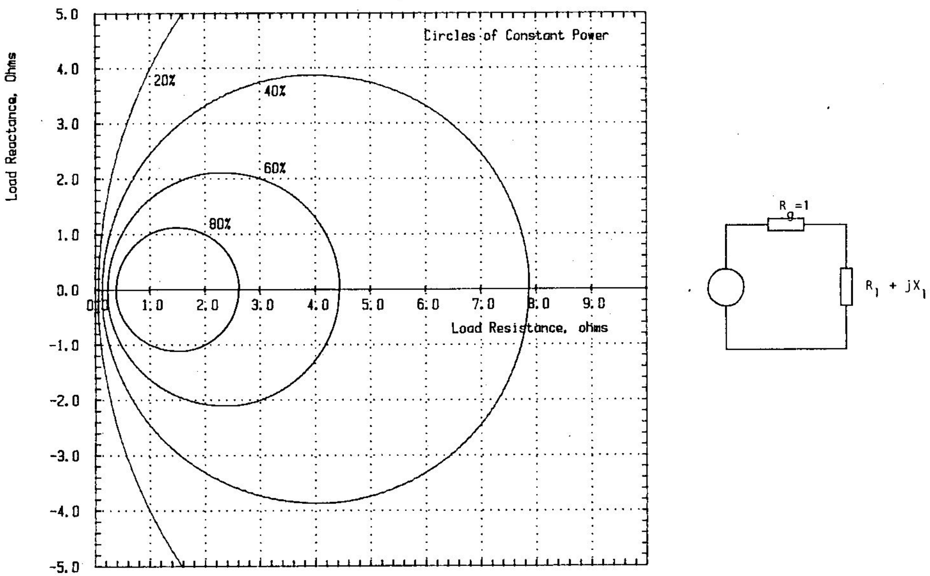


Fig 2 Load power as a function of load impedance: circles of constant power.

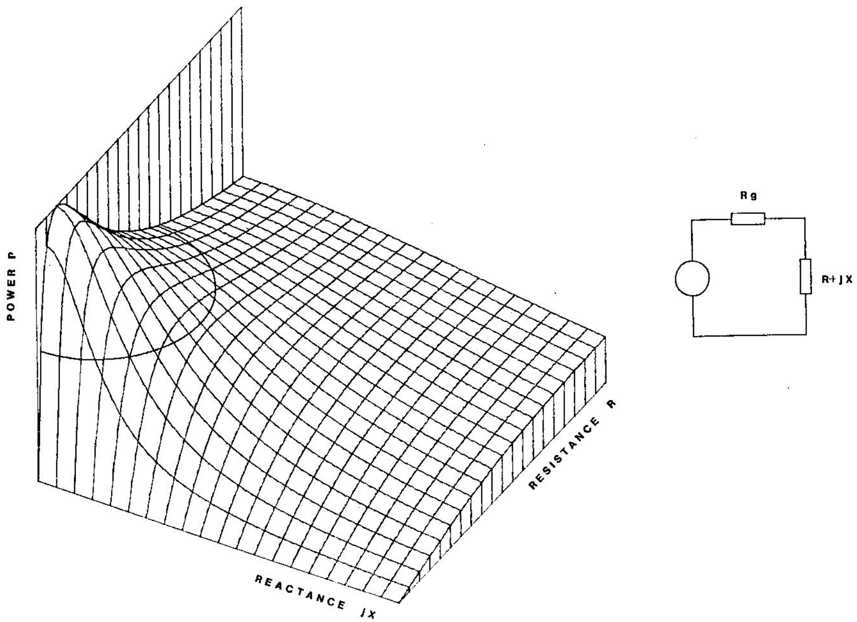


Fig 3 Power-Impedance space.

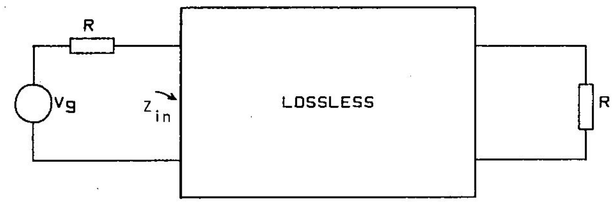


Fig 5 Doubly terminated linear, passive, lossless filter.

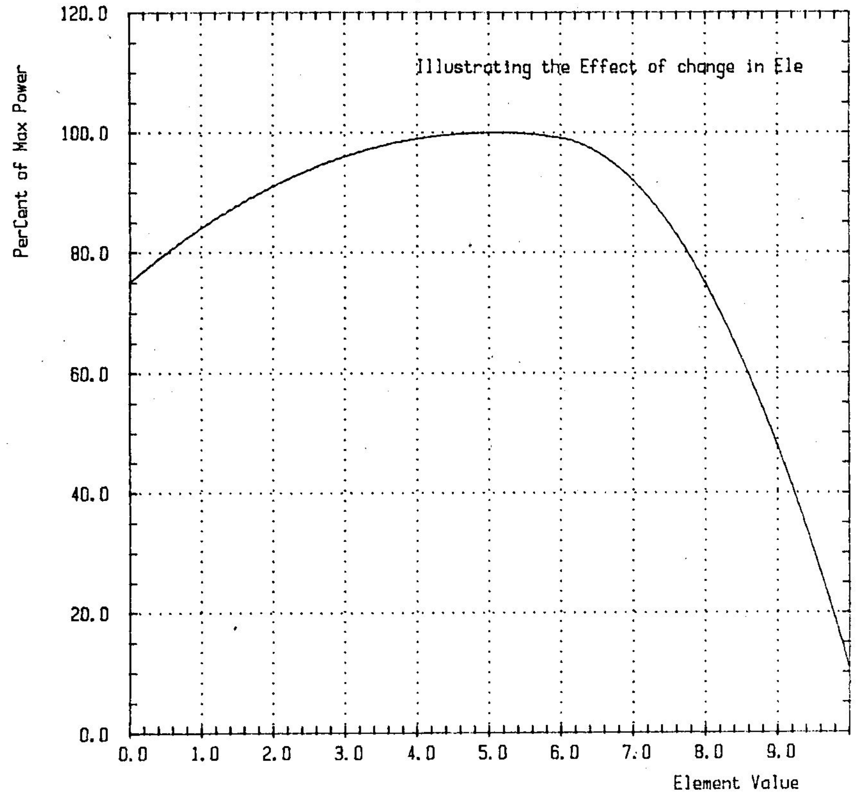


Fig 6 Output power variation due to a change in element value. For purposes of illustration, an optimum value of 5 was chosen. The illustration is valid at a finite frequency in the passband of the filter at which maximum power transfer takes place.

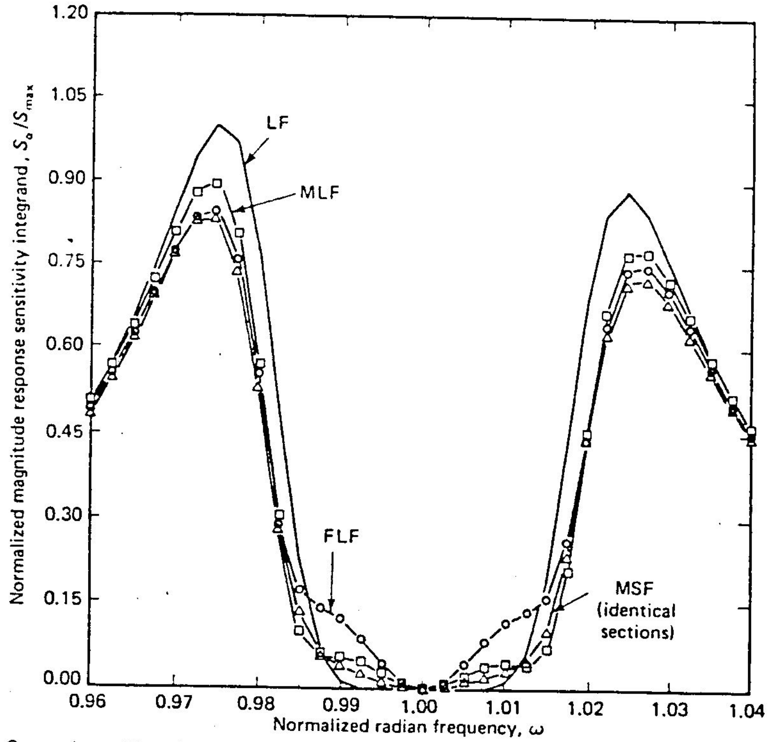
transfer function. From the transducer factor, it is a small step to get a reflection coefficient (the fraction of available power not absorbed by the load), which brings us back to the Smith chart, which is nothing else than a relationship between the reflection coefficient and impedance.

This theory had an immense impact. Modern crystal-, mechanical- and transmission line and waveguide filters are all derived from LC prototypes designed with the so-called insertion-loss theory. The excellent performance of these filters is a direct consequence of the maximum power theorem. In the passband, these filters provide an optimum (or near optimum) match to the generator. Consider a single element in the filter. Should the value of this element perchance increase, output power must decrease. On the other hand, when the value of the element decreases, output power also decreases. It is obvious that a curve relating output power and the element value has a maximum (and therefore zero slope) at the optimum element value, as shown in Fig 6. The zero slope implies low sensitivity to small changes in the element value, one of the outstanding characteristics of a doubly terminated filter designed for an optimum impedance match.

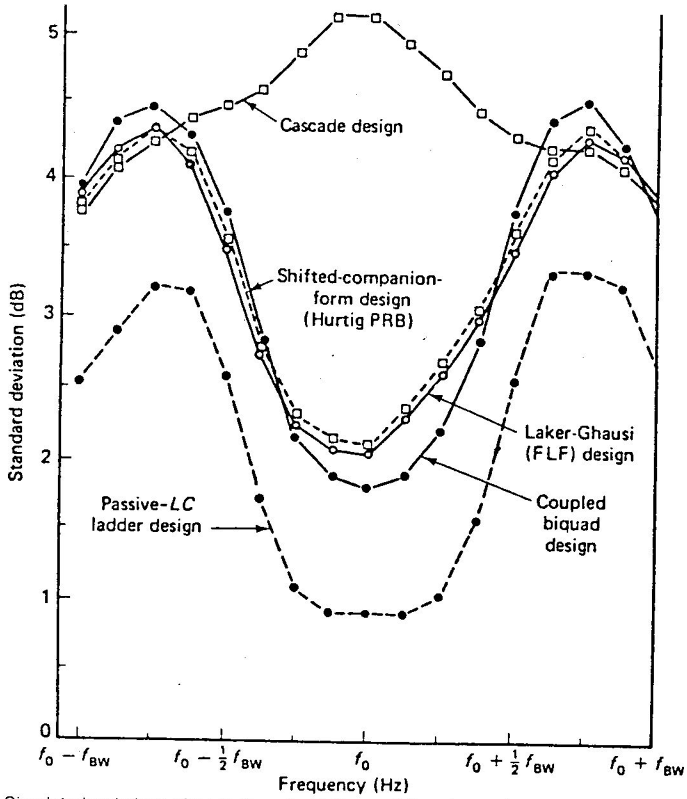
This characteristic of the doubly terminated filter in turn has had an impact of its own. It has been clearly demonstrated that RC-active and digital filters which simulate doubly terminated passive filters exhibit low sensitivity [8]. In fact, the sensitivities of active filters that have been optimised by computer for low sensitivity, are not appreciably lower than those derived from LC prototypes [9]. This is illustrated in Fig 7.

Scattering parameters

The concept of reflected power (or scattered waves) was found useful for filter design. Because an ideal filter is a lossless network by definition, the power delivered to the load is uniquely determined by the input impedance and the related reflection coefficient. In practice, all networks are lossy to some extent. To characterise such networks in terms of power flow, more information is needed. The scattering parameters are a generalisation of the simple concept of reflected power. A linear two-port network is characterised by four parameters, denoting input and output reflection coefficients and power transmission coefficients in the forward and reverse directions with the two port network inserted between two reference impedances, normally two fifty ohm resistors.



Comparison of the gain response sensitivity S_α versus frequency for LF, MLF, FLF and MSF (with identical sections) realisations for a sixth-order Butterworth band-pass filter (I_{max} = 0,135 274).



Simulated variations of the sixth-order Butterworth band-pass filter (1,732 % passive component tolerances).

Fig 7 Sensitivity performance of various RC-active filters. Taken from reference 9.

Scattering parameters had their origin with physicists who studied wave phenomena. They were brought to the attention of electrical and electronics engineers by Belevitch [10] and Carlin [11] in the early fifties. They turn out to be the most general set of parameters, existing for all passive and most active networks. This is more or less obvious as most useful systems handle infinite amounts of power.

It is therefore a pity that a working knowledge of these parameters, based ultimately on the maximum power transfer theorem, is very much confined to microwave engineers.

"If you want to know how much Escom cares about wildlife, ask the Cape Vulture."

Dr. John Ledger, Endangered Wildlife Trust.

Like so many of our country's indigenous birds and animals, the Cape Vulture is an endangered species.

Some years ago it was discovered that Cape Vultures were being electrocuted in large numbers as a result of roosting on the pylons of live powerlines, causing frequent power failures in certain areas.

In trying to solve what was originally a technical problem, Escom's engineers consulted with a group of experts on the behaviour and habits of the Cape Vulture.

Escom established a Bird Research Committee to conduct ongoing research into

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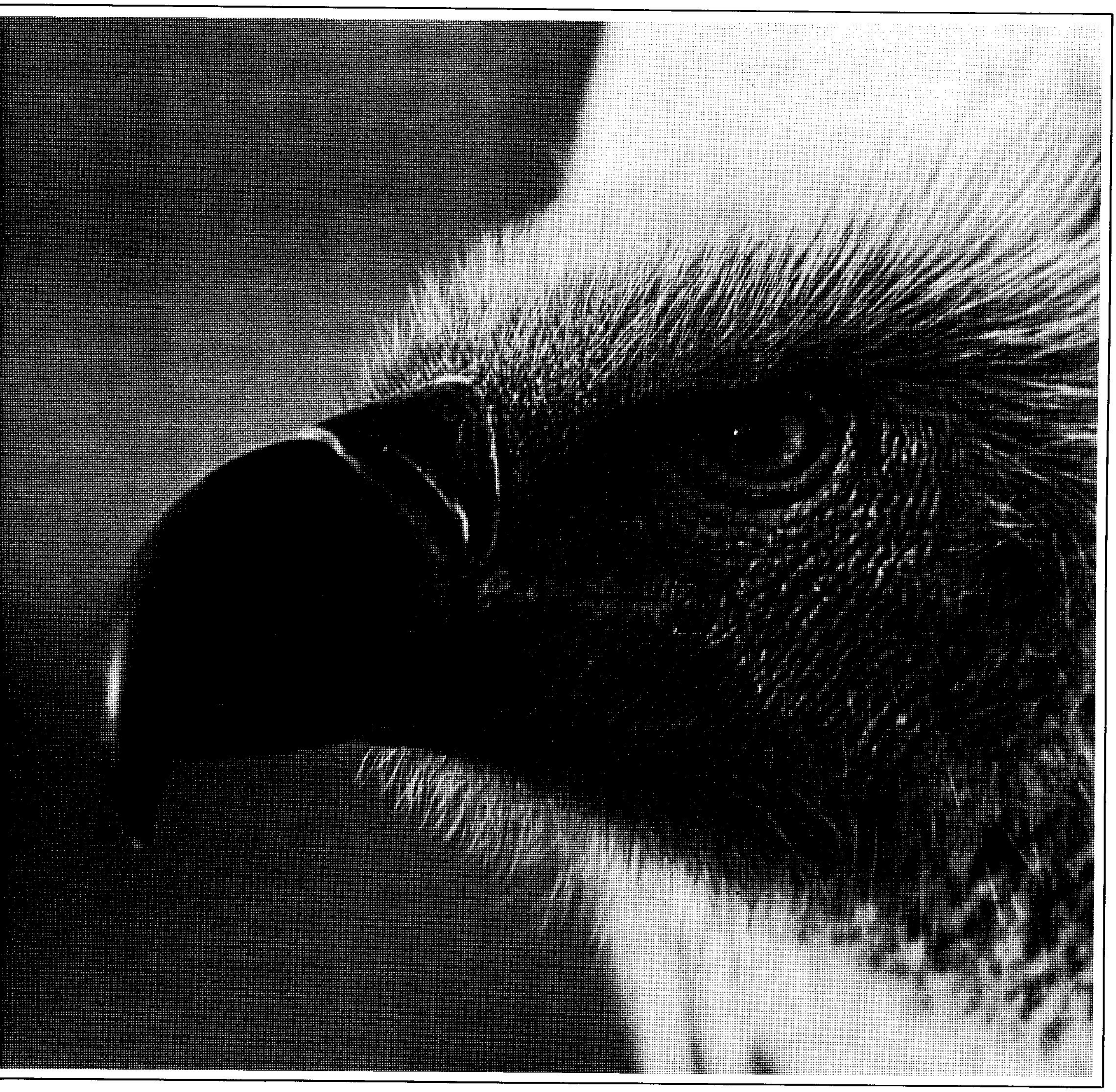

interactions between birds and powerlines. It was imperative to try and prevent any further fatalities not only among the Cape Vulture, but among all birds. Burying the powerlines was out of the question, because of the vast expense — estimated at hundreds of millions of rand. What was needed was some means of protecting the vultures from electrocution.

It was decided to avoid using hazardous pylon designs when routing new lines through areas where vultures occur. In critical areas special perches were fitted to more than 400 pylons, greatly improving the situation. More recently experiments with insulators have been carried out in an effort to finally eliminate this problem.

The ready cooperation between Escom and environmental interest groups has removed one major hazard from the life of one of nature's most majestic wild creatures.

This is one way Escom tries to minimize the impact of its activities on the environment.

For further information write to the Public Relations Officer at Escom. P.O. Box 1091, Johannesburg 2000.

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Impedance matching

The impedance matching problem is an extension of the resistively terminated filter.

Consider the network shown in Fig 8. The first one is a passive filter terminated by two resistors. The last element may be a shunt capacitor. The filter problem is to design the lossless network to realise a given transfer function.

The second circuit poses a new problem. A load which contains a shunt capacitor, must be matched (or deliberately mismatched) to a generator with a resistive output impedance, so that a specified transfer function is realised, usually over as wide a bandwidth as possible. Clearly, the two problems have a lot in common. One solution to the impedance matching problem is to search standard filter tables for a suitable filter which has a reactive element of at least the required value at the required place.

The solution to the problems entails the definition of the optimal filter response which will result in a maximum value for the last reactive element. Bode [12] solved this problem for one prescribed reactive element in the load. The ideal behaviour of a constant-gain transfer function, and the associated reflection coeffficient, is shown in Fig 9. A simple relationship exists between the maximum load reactance and the maximum value of the reflection coefficient, S_{max}. This is an excellent example of give and take: if the designer is willing to settle for a poor reflection coefficient, he can get as much bandwidth as he wants.

Bode's result was generalised for loads containing an arbitrary number of reactive components by Fano [13] and Youla [14]. Youla's mathematical dissertation is a challenge to read.

The general impedance matching problem, prescribing an impedance match (or a deliberate mismatch) over an arbitrary frequency interval between two complex impedances, as shown in Fig 10, remains largely unsolved analytically. While solutions have been obtained for specific cases, the general problem still merits attention. At the moment, the best approach seems to be computer-aided network optimisation; the theory for an analytical solution gets completely out of hand.

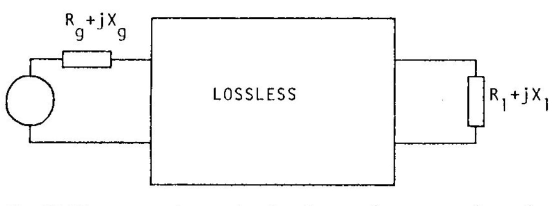

Fig 10 The general complex load, complex source impedance matching problem.

On a lighter note

Impedance matching is mathematically involved; most people probably find the subject boring. However, there are certain parallels to be drawn between this technical subject and everyday living.

We often hear that a husband and wife complement each other. Could this imply they have the same 'real parts', such as a liking for gardening or mountaineering, but opposite 'reactivities', or emotional patterns?

Communication between people requires a lot of give and take. To increase bandwidth, ie, to include more people in our conversation, may require acceptance of a larger reflection coefficient. In a country as diversified as South Africa, we would do well to try and match ourselves, in the impedance matching sense, to the other peoples of our country. Mismatch is often easy to spot, but difficult to rectify. Did Kennedy, for instance, have a problem with reactivity, or was the real part perhaps missing?

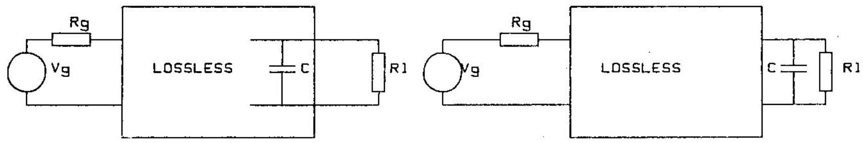

Fig 8 The impedance matching problem. A load containing a reactive element must be matched to a generator so that a prescibed transfer function is obtained. The figures clearly show the relationship to the doubly terminated filter.

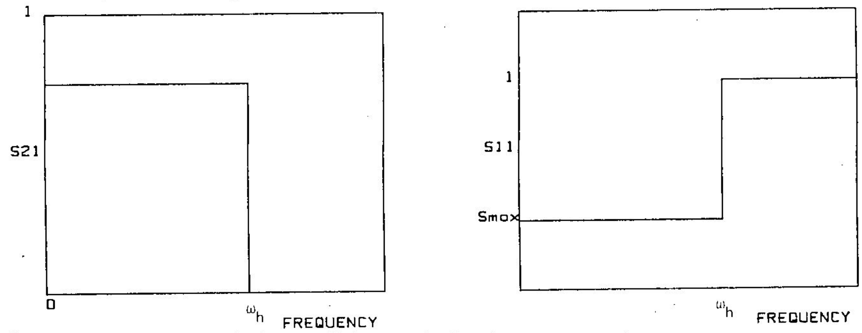

Fig 9 Ideal power transmission coefficient and reflection coefficient for optimum constant-gain requirement. The passband extends to ω_h. For a given reactive load, bandwidth can be increased by accepting a larger in-band reflection coefficient.

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Torque pulsation of induction and synchronous motors due to supply distortion

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Torque pulsation has become a matter of concern, chiefly because of the introduction of power electronic converting equipment. Motors may be supplied by imperfect electronic converters which add distortion to the desired output. Alternatively they could share a supply with equipment incorporating electronic devices which inject harmonics and unbalance into the system of finite impedance. This causes supply voltage distortion to which motors may be sensitive.

Not all disturbances are generated by power electronic devices. The most common system distortion is voltage unbalance which apart from resulting in unequal phase currents in the motor's stator and overheating, also develops double frequency pulsations of torque as shown in Fig 1. This in itself is not a disaster from the mechanical point of view provided resonances in the driven system do not coincide with this excitation. The inertia of the rotor attenuates the torque pulsations for fixed frequency operation. Single phase motors by the very nature of the power transfer from the supply develop torques for which the amplitude of the pulsation is virtually equal to the mean value and they operate quite satisfactorily. Why then is there a need to establish the exact nature of the torque developed by the motor?

Variable speed drives employing these motors depend on frequency to change their speed and in many cases to either run up from, or operate in, the near-standstill or standstill region. Electronic converters perform the frequency conversion. They are comparatively expensive devices and their incorporation in a variable speed drive makes it essential to gain maximum benefit from their ability to vary both frequency and voltage over a wide range. The performance of the motor must therefore be enhanced by maintaining its operation within its 'slip window' under all conditions. The slip window is the range of rotor slip frequency between the maximum positive and negative torques the motor is capable of delivering for a given airgap flux. The slip window is independent of stator frequency and operation within its limits yields maximum torque per ampere for a given flux.

If the motor slip is maintained in this region the only significant flux in the machine is that excited by the fundamental frequency magnetising stator current of fundamental pole number.

Phase band, tooth and current harmonic flux distributions may be regarded as inhibited by the rotor. Deep bar motors which operate at high efficiency have narrow slip windows and perform almost like synchronous motors. A 10 Hz slip window would therefore require a lower frequency limit for the inverter of 5 Hz if the motor is to deliver its maximum torque at standstill.

There are two hazards with regard to torque pulsation which result from the use of a frequency range from virtually zero to multiples of supply frequency. In the first instance it is most difficult to avert the excitation of mechanical resonances for such a range of frequencies for the drive system. Secondly the electronic converter, essentially a controlled switch, produces a stepped rotation of the phase of the output voltage or current which at low frequencies implements repeated impulses of torque. This will make any mechanical system behave unpleasantly and cause it to ring at its natural frequency. Converter development has therefore concentrated on the low frequency region to produce units which, in conjunction with the motor, will deliver smooth torque from standstill upwards to the maximum value contemplated.

Higher switching rates and energy storage elements modify the stepped nature of the converter and persuade it to deliver a more continuously varying sinusoidal output. Pulse width and more complex amplitude modulated systems have provided the solution at the expense of higher switching frequencies, increased energy storage and switching losses and more costly components.

Since cost has to be offset against performance, it is important to be able to plot the instantaneous torque delivered by a given converter configuration and motor in the absence of suitable torque meters. This contribution presents a method which makes it possible to calculate instantaneous torque as a function of time. The derivation uses measured values of fundamental and harmonic current components and their phase angles rather like power is calculated from voltage, current and their relative phase angle.

Creditable publications [1-5] have appeared which show how torque may be calculated using the current and voltage differential equations or transformations of these expressions. The reliability of the answers are subject to the accuracy of the parameters employed in the calculations. The stepped nature of the driving functions involved embrace a wide range of frequency which make the assumption of frequency independent parameters questionable.

The torque time relationships presented here were obtained by using measured values of current and their phase angles for several machines in the laboratory when subjected to distortion. Confirmation of the results using a torquemeter is desirable but existing strain gauge torquemeters were found to be unsatisfactory, particularly at low speeds and frequencies when the torque consisted of a series of impulses which excited the natural resonance of the motor rotor and the rather compliant torquemeter shaft. This ringing was not detectable in the stator current and it was assumed that this did not influence the electrical torque produced in the motor.

Method of calculating instantaneous torque

The derivation of the instantaneous torque time function is by integration of the product of fundamental flux and all current distributions of fundamental pole number, point for point around the circumference of the airgap of the motor for each instant of time of one repeated cycle of the fundamental frequency at which the motor is excited. These integration totals are expressed in per unit of the integration sum of the point for point product of the fundamental time varying flux and current distributions which revolve synchronously and produce the constant mean torque of the motor.

Nett torque with respect to the integral around the circumference of the motor, is only produced by the interaction of current distributions having angular frequencies according to the frequencies of their current components but space distribution or pole numbers which are identical to the fundamental frequency flux distribution. The frequencies of pulsation are derived from the relative angular velocity between the particular component considered and the fundamental flux distribution and the common fundamental pole number of the machine. Thus a 5th harmonic negative sequence set of currents produce a current distribution which revolves relative to the fundamental positive sequence flux distribution at six times fundamental synchronous speed and results in a torque pulsation which is six times the fundamental frequency. In the same way a 7th positive sequence current harmonic also produces a torque pulsation at six times the fundamental frequency.

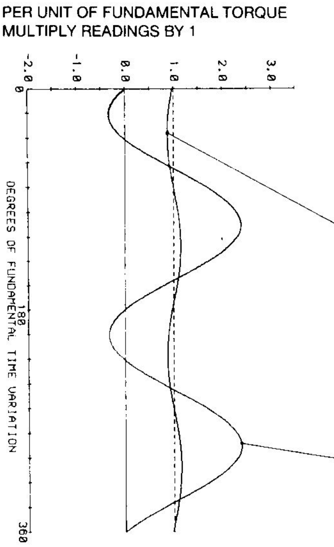
Since the pole number is common for all the interacting components taken into the calculation, the winding factors are the same and the current distribution magnitudes are thus related to current by the same constant for all components. Phase current rms values may therefore be used instead of current distribution magnitudes provided torque is expressed on a per unit basis.

The amplitudes of the pulsating components are given by the product of each current magnitude and the common fundamental flux magnitude and their phase relationships set by the phase angles of the currents relative to the fundamental voltage of the motor. The mean constant torque produced by

*Consultant

the fundamental frequency has a magnitude given by the product of its amplitudes of flux and current and the cosine of the angle between the fundamental voltage and current phasors.

For the results which are displayed, provision was made for a maximum of 11 current components. The number of integrations was set at 180 or 1 for every degree of the fundamental time variation. This results in steps of 1 x 31 or about 30 deg for the highest frequency component considered. Each integration was resolved into 360/5 steps giving 12 960 evaluations of an expression consisting of 11 sine components. Better resolution may be achieved by considering more components and using smaller steps at the expense of more time for the computation of each curve. Using a desk type microcomputer programmed in Basic, each curve took 75 min to compute from the measured currents given in the corresponding tables. This time can no doubt be reduced considerably. Strictly speaking torque should be calculated using the rotor image component of stator current in the case of the fundamental. This is of no consequence in the case of the harmonic currents.



THREE PHASE MOTOR WITH AN UNBALANCED SUPPLY VOLTAGE

COMPONENT SEQUENCE	VOLTAGE PER UNIT	CURRENT PER UNIT	ANGLE DEG.
POSITIVE	1.0	1.0	-36
NEGATIVE	0.02	0.10	100

SINGLE PHASE INDUCTION MOTOR

COMPONENT SEQUENCE	VOLTAGE PER UNIT	CURRENT PER UNIT	ANGLE DEG.
POSITIVE	1.0	1.0	-41
NEGATIVE	Neglected	1.0	-41+180

Fig 1 Torque developed by three and single-phase motors.

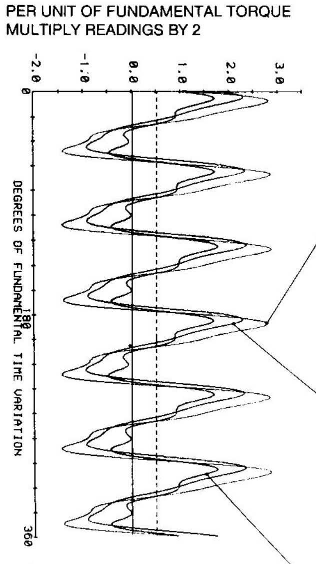
Torque time relationships produced by quasi-square inverters feeding induction motors

Tables of voltage, current and phase angles and the computed torque time curves are given in Figs 2 and 3. The corresponding inverter voltage waveforms and in one case the current waveform, have been added. The dashed lines correspond to the mean or fundamental output. In the case of no load these torques merely supply the windage and friction losses and torque reversal occurred for each machine.

When loaded the per unit torque may be calculated as follows:

15,3 kW Motor at 0,8 load

$$\text{Per unit torque } \frac{15\,300 \times 0{,}8}{2\pi \times 50} = 39{,}0\,\text{Nm}$$



15.3kW MOTOR AT NO LOAD

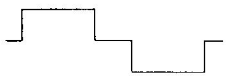
HARM. NO	VOLTS	AMPS	ANGLE
1	196.8	5.54	-65.7
-5	47.9	6.42	-63.1
7	29.2	3.05	-108.1
-11	29.6	2.02	-76.3
13	9.8	0.53	-149.4
-17	17.3	1.20	-78.7
19	1.6	0.18	-58.7

5HP MOTOR AT NO LOAD

HARM. NO	VOLTS	AMPS	ANGLE
1	114.0	2.35	-72.4
-5	22.5	1.30	-51.8
7	17.3	0.77	-63.6
-11	10.4	0.32	-32.4
13	9.9	0.27	59.8
-17	8.1	0.17	-15.5
19	6.84	0.12	-46.6

55kW MOTOR AT NO LOAD

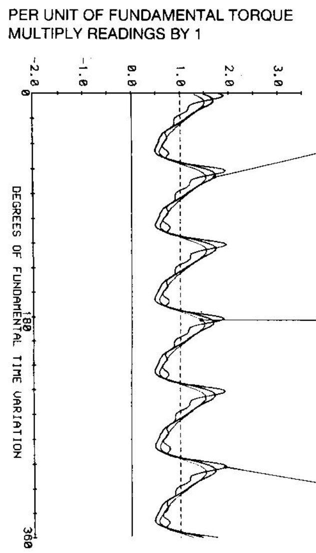
HARM. NO	VOLTS	AMPS	ANGLE
1	205.7	12.24	-80.6
-5	54.0	2.70	-56.5
7	30.2	1.17	-111.2
-11	33.2	0.91	-66.7
13	7.5	0.23	-106.3
-17	14.7	0.85	-60.3
19	4.1	0.31	-94.0



INVERTER VOLTAGE WAVEFORM

Fig 2 Pulsating torques produced by three cage motors at no load when fed by quasi-square inverters.

The torque pulsation is at six times the fundamental frequency as may be expected for a 3-phase bridge inverter. The main contributors are the negative 5th and positive 7th time harmonic currents which may be read from the tables. The curves have a saw tooth outline with the steep rise in torque corresponding to the stepped phase advance produced by the



15.3kW MOTOR AT 0.8 OF FULL LOAD

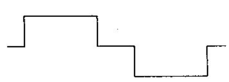
HARM. NO	VOLTS	AMPS	ANGLE
1	203.1	20.85	-17.0
-5	47.3	8.49	-43.1
7	29.4	3.29	-83.9
-11	30.4	2.84	-40.9
13	10.5	0.45	-112.4
-17	20.2	1.27	-44.5
19	1.1	0.09	68.6

5HP MOTOR AT 0.5 OF FULL LOAD

HARM. NO	VOLTS	AMPS	ANGLE
1	126.0	5.22	-26.9
-5	25.4	1.25	-56.3
7	20.8	0.78	-74.5
-11	12.1	0.29	-42.4
13	11.6	0.27	-80.3
-17	9.1	0.13	-36.8

CURRENT FED MOTOR

1	1.000	-36.0
-5	0.200	-36.0
7	0.143	-36.0
-11	0.091	-36.0
13	0.077	-36.0
-17	0.059	-36.0
19	0.053	-36.0
-23	0.043	-36.0
25	0.040	-36.0
-29	0.034	-36.0
31	0.032	-36.0



INVERTER CURRENT AND VOLTAGE WAVEFORMS

Fig 3 (a) Torques produced by two loaded voltage-fed motors.
(b) Torque produced by a loaded current-fed motor.

electronic inverter. The pulsation is at its worst at no or light load. This is shown by Fig 2 and was supported by the audible vibration in the couplings of the motor to the dynamometer in the laboratory. At light load the pulsating torque components can easily exceed the mean torque. For voltage fed inverters the applied voltage harmonic components experience a motor impedance at short-circuit. Thus a 5th harmonic voltage would see an overall impedance which is comparable to the full load fundamental frequency impedance of the motor and induce a current which is about a fifth of full load. At no load the fundamental and fifth harmonic currents can become comparable as shown by the tables. The pulsating torque components will then exceed the fundamental mean torque since as explained, the latter is given by the product of its amplitudes of flux and current times the cosine of the angle of displacement between its distributions. The pulsating torques, on the other hand, have magnitudes given by the product of the amplitudes only. At light load the fundamental power factor is very low reducing the fundamental torque.

In the case of current fed inverters the same argument applies and although the current ratios are inversely related to the harmonic numbers, it is incorrect to assume that the torque pulsation amplitudes are given by fundamental torque divided by harmonic number as stated by some authors. Fig 4 shows the deterioration of the output torque of a current fed inverter at light load. At no load the magnetising current which the inverter has to supply, invokes current harmonics which will cause pulsation swamping the fundamental steady torque produced by the rotor fundamental current.

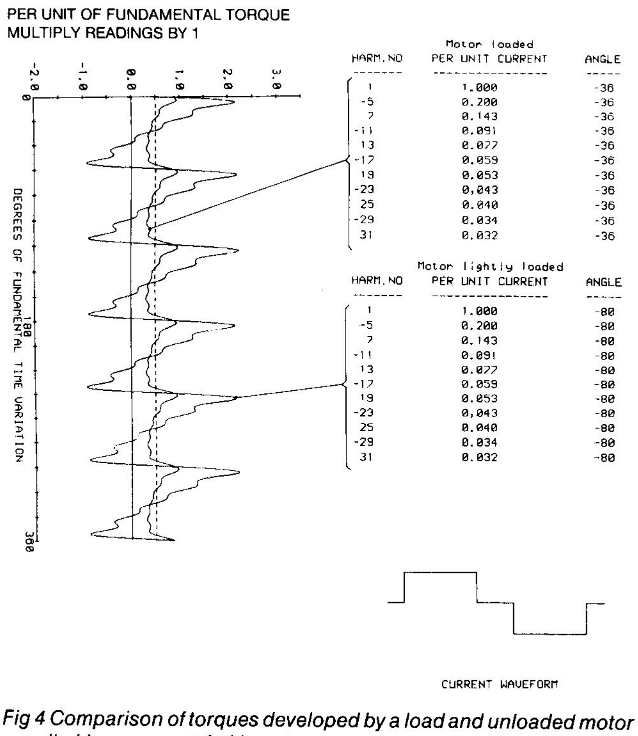


Fig 4 Comparison of torques developed by a load and unloaded motor supplied by a current-fed inverter.

Figs 2 and 3 also illustrate the influence the machine parameters have on the pulsation of torque. The 55 kW motor when compared with the others develops less pulsation because of its relatively higher harmonic impedance. Motors, inverters and the mechanical load should be considered as a system in terms of their desired function. It is surely uneconomic to provide a costly inverter to avoid a resonance when this frequency can be avoided by a control strategy. Torque pulsation may be reduced by the design of the motor which has some of its normal design constraints removed provided it only operates in its slip window. Starting torque, for instance, is no problem as the motor can be started at its maximum torque.

In Fig 3 the simulated current-fed results produce higher torque pulsations as the harmonic currents are not controlled by the machine's impedance but imposed by the constant current feature of the inverter.

An improved inverter

A reduction in torque pulsation is illustrated by the torque time curves in Fig 5. It is achieved by modifying the voltage waveforms with the introduction of a more complex switching function for the inverter. This culminates in a mixture of six and 18 pulses per cycle.

The reduction of torque pulsation in this manner is not only desirable from the point of view of producing a smoother drive, but it also improves the efficiency. At higher output frequencies this advantage is offset by switching losses and control strategies in many cases revert to the simpler waveform in this region.

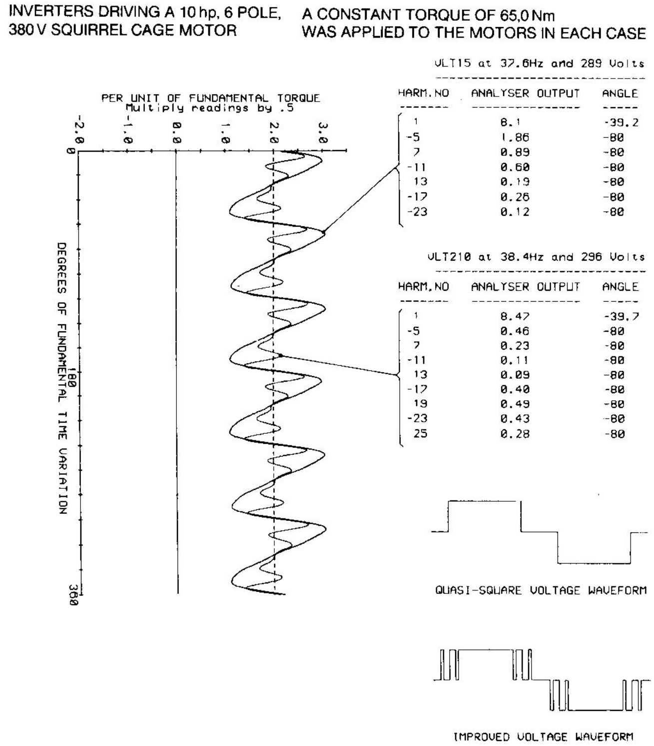


Fig 5 Comparison of motor torques for voltage-fed quasi-square and PWM inverter waveforms.

Torque pulsation due to distortion of the supply voltage

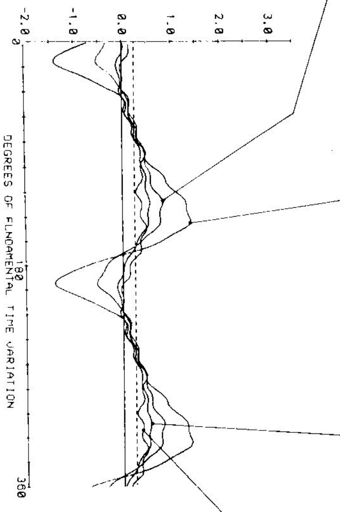
A bridge rectifier was connected between the red and yellow lines of a 650 kVA alternator and made to supply 200 A to a dc motor. To enhance the distortion this load produced, an impedance was inserted in the damper winding circuit of the alternator to raise its negative sequence and harmonic impedances.

The results for four different machines operating at no load are presented in Fig 6 with tabulated values of volts, amps and phase angles read with a harmonic and phase analyser.

The pulsation of torque has a fundamental component at twice the supply frequency due to the unbalance distortion. If one examines the overall torque pulsation curve, the conduction period of the rectifier can be identified. During this period the torque falls because of the regulation induced by the rectifier current. When conduction ceases the voltage recovers as does the torque produced by the motor.

An additional incidental illustration of this diagram is the ability of the larger machines to attenuate the distortion caused by the bridge rectifier.

PER UNIT OF FUNDAMENTAL TORQUE
MULTIPLY READINGS BY 4



15,3kW MOTOR AT NO LOAD

HARM.NO	VOLTS	AMPS	ANGLE
1	217.7	6.48	-74.3
-1	13.04	4.29	99.3
3	8.96	2.24	-134.0
-3	8.68	1.49	140.3
5	2.73	0.25	-168.6
-5	2.20	0.31	139.5
7	2.01	0.20	156.5
-7	1.90	0.07	43.58
9	1.28	0.11	69.9
-11	1.09	0.10	-72.9
-17	4.66	0.26	-117.5

5HP MOTOR AT NO LOAD

HARM.NO	VOLTS	AMPS	ANGLE
1	220.8	2.89	-83.34
-1	10.0	1.81	101.5
3	11.6	0.74	-115.4
-3	10.4	0.68	142.0
5	0.8	0.03	82.5
-5	3.3	0.22	109.9
7	0.9	0.03	151.9
-7	2.1	0.06	74.1
9	1.7	0.03	51.0
-9	1.5	0.03	7.0
-17	4.3	0.06	-110.2

55kW MOTOR AT NO LOAD

HARM.NO	VOLTS	AMPS	ANGLE
1	219.9	13.96	-84.9
-1	8.27	1.61	88.3
3	9.61	0.99	-143.1
-3	8.96	0.31	136.3
5	2.72	0.06	152.5
-5	2.47	0.05	110.8
-7	1.88	0.09	-85.0
9	1.52	0.08	48.8
-9	1.33	0.04	-38.3
-17	5.06	0.13	-134.8

1300kW MOTOR AT NO LOAD

HARM.NO	VOLTS	AMPS	ANGLE
1	3453.8	38.13	-81.6
-1	22.6	5.56	95.4
3	27.5	2.15	-126.2
-3	26.5	2.20	43.2
5	12.1	0.38	156.2
-5	16.7	0.70	166.5
-7	7.8	0.16	-48.3
-17	47.9	0.82	-179.5
19	22.1	0.31	-150.0

Fig 6 Pulsating torques of four motors operating in parallel with a 200 A line connected bridge rectifier supplied by a 650 kVA alternator.

Conclusions

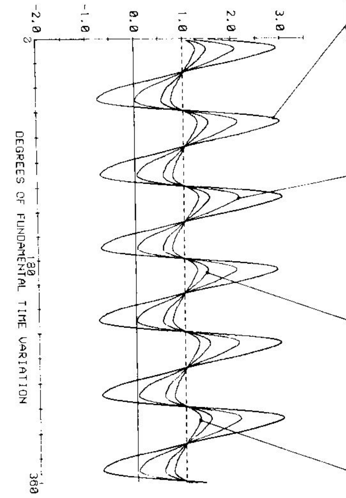
If these torque calculations are correct it would appear to be unwise to adhere to the constant voltage to frequency relationship aimed at maintaining constant flux in the motor.

For voltage fed machines, the harmonic currents which flow in the stator for a given frequency are a function of the applied voltage and the short circuit harmonic impedance of the motor. They are almost independent of load and as it is reduced the harmonic currents become comparable with the fundamental current and torque pulsation increases while the efficiency deteriorates. The 15,3 kW machine in Fig 2 shows that at no load its 5th harmonic current exceeds the fundamental value.

Fig 7 examines the torque pulsation produced by a 7,46 kW motor when delivering a reduced output of 2 kW. It certainly appears wise to operate the motor at 200 V rather than 400 to realise a better efficiency and a smoother torque. Inverter driven motors should never be operated at full voltage when delivering light or no load.

The data used for the calculation of the torques shown in the diagrams were obtained from measurements on actual machines in most cases. This involved the use of a harmonic and phase analyser. The calculations may also be based on predictions of models or equivalent circuits of the motor provided these make some attempt to allow for the behaviour of the motor parameters with respect to frequency particularly the rotor resistance.

PER UNIT OF FUNDAMENTAL TORQUE
MULTIPLY READINGS BY 1



TORQUE PULSATIONS PRODUCED BY VLT15
DRIVING 6 POLE 7.46kW BULL MOTOR

MOTOR DELIVERING 2.0 kW

HARM.	VOLTS	AMPS	ANGLE	*EFFIC
1	400	9.3	-68.9	82.0
-5		3.83	-80	
7		1.83	-80	
-11		1.24	-80	
13		0.39	-80	*SLIP=0.45
-17		0.54	-80	
-23		0.25	-80	

HARM.	VOLTS	AMPS	ANGLE	*EFFIC
1	300	8.0	-55.9	87.6
-5		2.87	-80	
7		1.38	-80	
-11		0.93	-80	
13		0.29	-80	*SLIP=0.80
-17		0.40	-80	
-23		0.19	-80	

HARM.	VOLTS	AMPS	ANGLE	*EFFIC
1	200	8.3	-37.8	90.0
-5		1.92	-80	
7		0.92	-80	
-11		0.62	-60	
13		0.20	-80	*SLIP=2.0
-17		0.27	-80	
-23		0.12	-80	

HARM.	VOLTS	AMPS	ANGLE	*EFFIC
1	150	10.8	-33.9	85.2
-5		1.44	-80	
7		0.69	-80	
-11		0.46	-80	
13		0.15	-80	*SLIP=4.4
-17		0.20	-80	
-23		0.09	-80	

Fig 7 Reduction of torque pulsation and improvement of efficiency of a lightly loaded induction motor by voltage and frequency control.

Acknowledgements

These results are the outcome of work sponsored by the Electric Vehicle Committee of the CSIR. The Danfoss inverters were on loan from J L Clarke Engineering and Cape Electronic Devices.

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ERRATUM

In die uitgawe van *Elektron*, Februarie 1985, p 27, die affiliasie van P J van Hoof was foutief aangedui as Universiteit van Pretoria. Sy affiliasie is Fakulteit van Ingenieurswese, Randse Afrikaanse Universiteit.

Single-phase auto-reclosing: Philosophy and experience in Southern Africa+

PART 2

R R Slatem* PrEng, BSc (Elec Eng)(Rand) FSAIEE

Practice in the Republic of South Africa

Initially the practice was to introduce single-phase reclosing on relatively long single line supplies only. The theory was that where there was a redundant circuit the probability of requiring single-phase reclosing would be low. Even when the redundant circuit was planned for one or two years later it was considered unnecessary to introduce the additional complication of single-phase reclosing on the initial line. This theory proved to be entirely false. If a supply is important enough to justify a redundant line, then the continuity of supply should be ensured even when the redundant line is out for maintenance. And difficulties with line design and construction, network changes, etc have resulted in outage times of the redundant lines far in excess of those anticipated. So in many instances it would have been of considerable advantage to have had the initial line equipped with single-phase reclosing from the outset.

It is the present policy to provide the scheme on selected single lines at 132 kV and on all lines of 220 kV and above even if multiple lines are planned and installed at the outset. At the 400 kV level, single-phase reclosing of series compensated lines has also been installed recently.

To improve the stability of important loads associated with the coal-to-petrol conversion industry, certain lines which were only equipped for three-phase auto-reclosing have been modified to provide single-phase reclosing.

In the majority of instances the single-phase reclosing has been installed to improve continuity of supply and load stability rather than to maintain system synchronous stability.

Dead times of the order of 0,6 s have been successfully employed at all voltage levels. But, as synchronous stability is seldom a problem for single-phase faults and reclosing, it has become standard practice to set the single-phase dead time at 1,1 s. This has the advantage of longer de-ionising times for the majority of faults, with increased probability of a successful reclose. It is also possible to obtain successful single-phase reclosures for faults cleared in zone 2 time (0,5 s delay) if the communication link is out of service or for high resistance faults not detected by the first zone of the protection. For a fault in the end 15-20 per cent zone of the line, one end is then cleared in 0,5-0,6 s while the other end is cleared instantaneously. The nett total dead time of the faulted phase is reduced from 1,1 s to 0,5 or 0,6 s.

Auto-reclose cycle

Conventional practice allows for a single-phase trip and auto-reclose for a single-phase ground fault. If the reclose is unsuccessful a three-pole final trip is initiated.

Our practice is to trip three-phase if the single-phase trip and reclose is unsuccessful and to initiate a delayed, three-phase auto-reclosure, with synchronism check if necessary. With this unconventional cycle (see Fig 5), the line is automatically restored to service more frequently than with the conventional cycle in the majority of cases. This results from the fact that the most common cause of an unsuccessful single-phase reclose attempt is the presence of the object which initiated the fault, eg, bird, burning branch, grass or bush fire, at the instant of single-phase reclosure. During the dead time of the second, three-phase reclose attempt, which is usually between three and sixty seconds depending on whether the breaker is an air blast or minimal oil volume spring closed type, the cause of the fault disappears. The burning branch falls clear, the bush fire moves on, etc.

Teed lines

Single-phase auto-reclosing is applied on lines with a maximum of two tee points. A suitable breaker is installed at each tee point and this is tripped instantaneously on the appropriate phase for all earth-faults on the line and possibly on the adjacent sections too. Tripping the faulted phase at the tee point instantaneously removes the source of zero-sequence current infeed at the tee and consequently facilitates relaying of line earth-faults. There is no interruption of supply to the load at the tee points, or to loads beyond the line, as supply is maintained via the two healthy phases.

Long lines

In South Africa single-phase reclosing has been applied to only two lines where it was considered necessary to compensate for line capacitance coupling.

The first was a 300 km untransposed 400 kV line equipped with a single 100 MVAR shell-type shunt reactor. The reactor had already been purchased when it was decided to employ single-phase reclosing, so the

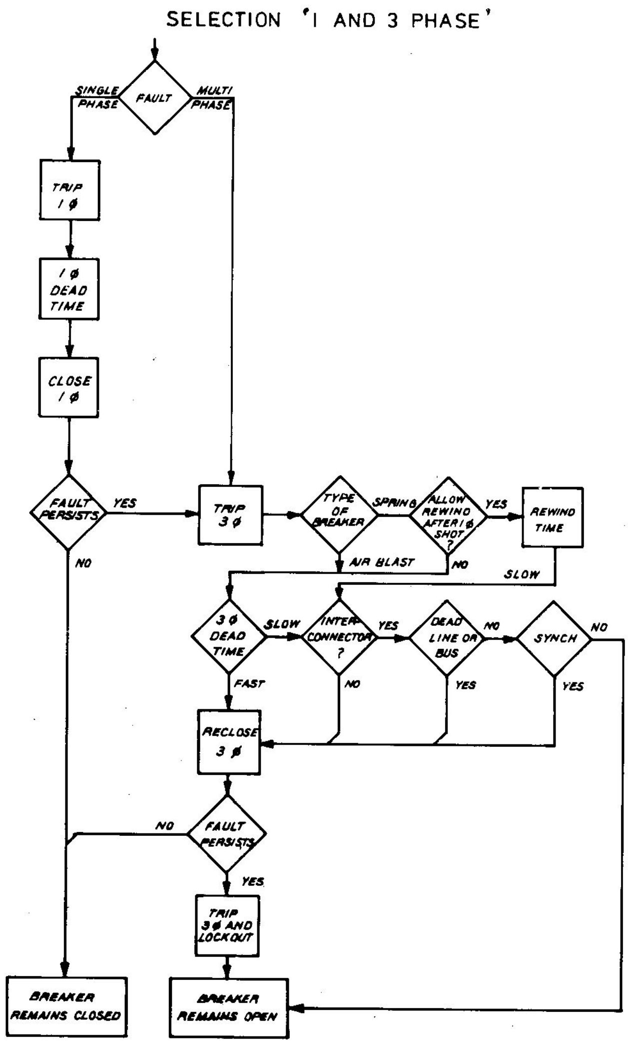

Fig 5

+Presented at the International Federation of Automation and Control Symposium on 15-19 September 1980 at Pretoria and reprinted with permission from Automatic Control in Power Generation, Distribution and Protection.

*Consulting Electrical Engineer (Protection Specialist)

Note: Certain additions have been made by the author who states that the philosophy and statistics given in this paper are those that applied at the time of the original publication. They do not necessarily reflect the status of single-phase auto-reclosing in Southern Africa since 1980.

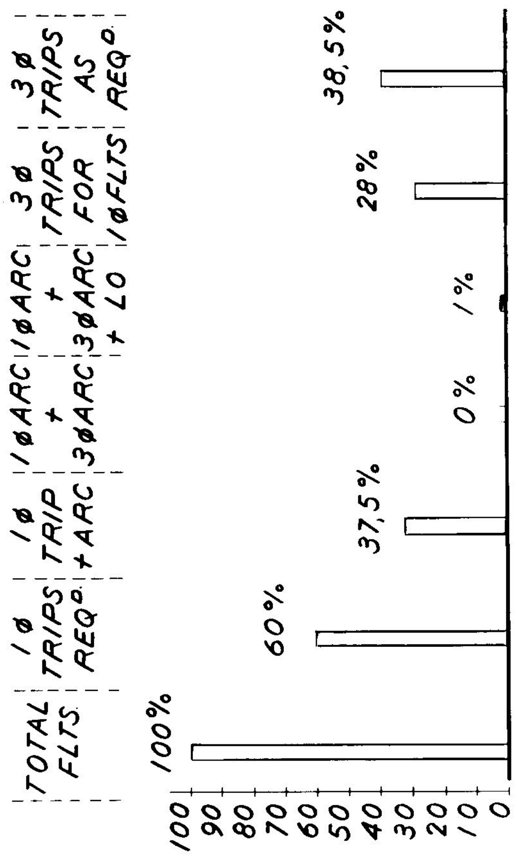

Fig 6 400 kV 1 φ arc.

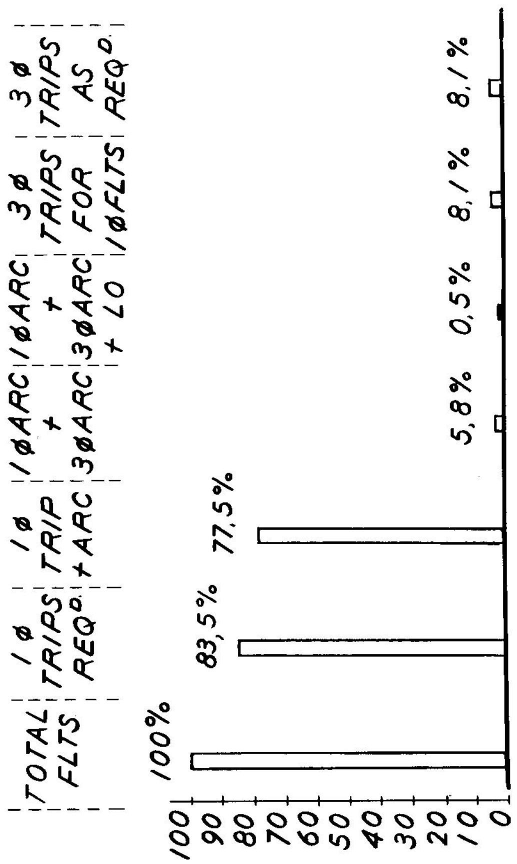

Fig 7 275 kV 1 φ arc.

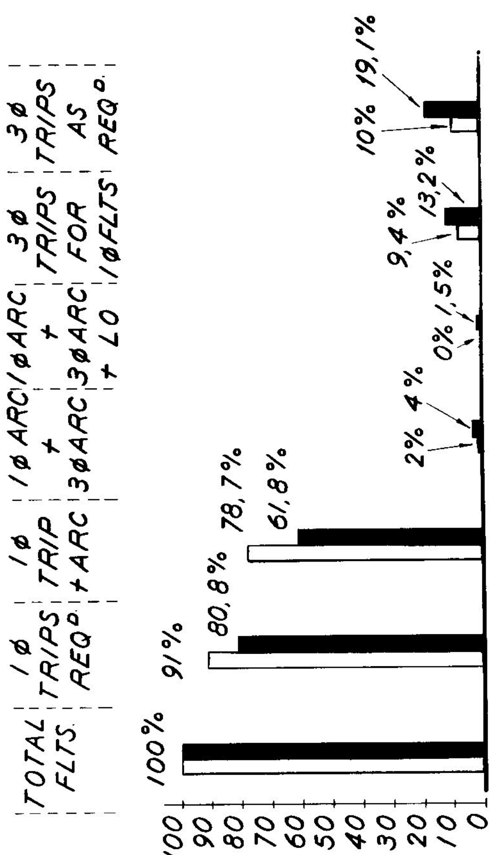

Fig 8 220 kV 1 φ arc.

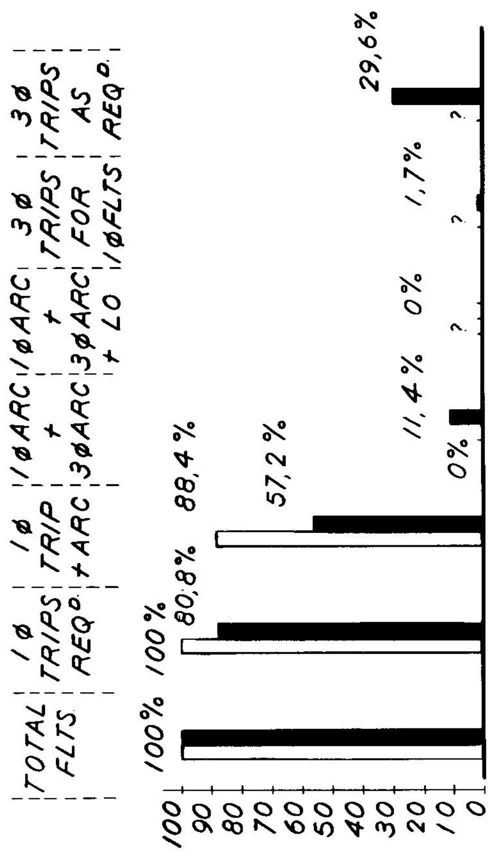

Fig 9 132 kV 1 φ arc.

degree of neutral compensation was limited by the available BIL of the reactor neutral point. A neutral reactor having taps at 0,56/0,68 and 0,81 h was installed on the 0,56 h tap. Details of the line are given in Appendix 2.

The second application was on a fully transposed 330 kV line of about 520 km length. The line was equipped with a single 70 MVAR shunt reactor at one end and two shunt reactors at the other. Each reactor has a reactance per phase of 1 556 Ohm and a neutral reactor of 1,59 h. The line parameters are given in Appendix 2.

The maximum length of line on which single-phase reclosing has been applied successfully without compensation, at the various voltage levels, is indicated below:

400 kV 196 km
275 kV 184 km
220 kV 160 km
132 kV 161 km

Protection mode

The distance protection is applied in the overlap mode on 132 kV lines of lesser importance where carrier communications are not provided. On lines of 220 kV and above, where carrier is always provided, it is applied in the permissive under-reach or the permissive over-reach mode.

Normally the communications consist of a single channel in each direction, phase selection being effected locally by the protective relays. Where network conditions will result in inadequate currents and voltages for correct phase selection, or to cover high resistance earth-faults, the faulted phase information can be transmitted on a 'per phase' basis via three communication channels.

Experience in the Republic of South Africa

General

The statistics recorded in Table 1 are for typical periods and based on the best information available. However, their accuracy cannot be guaranteed. They indicate that the application of single-phase reclosing in this country has been largely successful at all voltage levels except 400 kV.

These statistical results are also shown diagrammatically in Figs 6, 7 and 8 for 400, 275 and 220 kV respectively while Fig 9 shows the results for 132 kV.

During the development of the network some areas have had to be fed by single EHV lines for many years. Single-phase reclosing has been fully justified on the basis of the improved quality of supply afforded in these areas alone.

Table 1 summarises the overall performance at the various voltage levels while Tables 2-4 give the performance of typical lines.

Table 2 Performance of 400 kV lines

Line reference	A	B	C	D	E	F	G	H
Line length km	297	47	47	186	163	196	168	124
Total faults	17	27	11	5	3	4	2	14
1Φ Trips required	17	11	7	1	1	1	0	12
Successful 1Φ Trips +Arc	12	7	6	0	0	0	0	2
1Φ Arc +3Φ Arc	0	0	0	0	0	0	0	0
1Φ Arc +3Φ Arc +LO	0	0	0	0	0	0	0	1
3Φ Trips for 1Φ Faults	5	4	1	1	1	1	0	9
Correct 3Φ Trips	0	16	4	4	2	3	2	2

Discussion

The performance of the single-phase reclosing has been successful in general, outstanding on certain specific circuits with an exceptionally high fault incidence level, and disappointing on some 400 kV lines. The poor performance on the latter lines can be ascribed to an abnormally high incidence of multi-phase and developing faults due to salt pollution. The lines are only 47 km long so arc extinction is not a problem with dead times of 1,1 s.

On the longest 400 kV line about 300 km in length and with 17 faults over a two-year period we experienced 12 successful reclosures without loss of supply, five three-phase trips. There was no instance of a single-phase trip followed by a three-phase trip on reclosure. The line is equipped with a shunt reactor for compensation.[3], [4]

The success of single-phase reclosing on a particular 275 kV line 168 km in length will be observed from Table 3 reference F. The extraordinarily high fault incidence due to bird pollution would have made the continuity of supply completely unacceptable with three-phase reclosing. But with single-phase reclosing there were only 15 unnecessary supply interruptions out of a possible 258, ie 94 per cent successful reclosure.

The performance at the 220 kV level on an extensive single line supply network has likewise been highly successful. Without single-phase reclosing it would probably have proved necessary to double the transmission investment to provide the same order of continuity of supply.

The lowest voltage at which single-phase reclosing has been applied with success is 132 kV. As would be expected the percentage of successful single-phase reclosures at this level is lower due to the higher incidence of multiphase faults. Nevertheless the percentage of successful reclosures is still high enough to justify its application down to this voltage level.

Table 3 Performance of 275 kV lines

Line reference	A	B	C	D	E	F	G
Line length km	53	53	90	90	111	168	95
Total faults	6	5	8	8	18	264	48
1Φ Trips required	5	4	8	7	9	258	36
Successful 1Φ Trips +Arc	2	0	3	3	0	243	22
1Φ Arc +3Φ Arc	0	0	1	2	3	13	3
1Φ Arc +3Φ Arc +LO	0	0	0	0	0	2	0
3Φ Trips for 1Φ Faults	3	4	4	2	6	0	11
Correct 3Φ Trips	1	1	0	1	9	6	12

Table 4 Performance of 220 kV lines

Line reference	A	B	C	D
Line length km	102	160	116	98
Total faults	7	19	24	18
1Φ Trips required	5	14	22	14
Successful 1Φ Trips +Arc	3	13	20	6
1Φ Arc +3Φ Arc	0	0	0	3
1Φ Arc +3Φ Arc +LO	0	0	0	1
3Φ Trips for 1Φ Faults	2	1	2	4
Correct 3Φ Trips	2	5	2	4

Protection problems

Phase selection

One of the most important tasks of the protection is correct selection of the faulted phase. Normally this is effected by the zone 3 relays with under-impedance or off-set mho characteristics. Initially some incorrect phase selection was experienced when the under-impedance relays were set with a wide reach in an attempt to provide remote back-up protection. It was found necessary to reduce their reach to not more than 150 per cent of the protected line section. This is acceptable as the problem of local infeed has made it virtually impossible to achieve remote back-up on the network with distance type relays. In addition, the majority of faults for which remote back-up protection is required are earth-faults which are separately covered by sensitive overcurrent relays of the dependent time type.

In certain applications where there is a radial supply with a limited source of zero sequence current at the remote end, additional phase selection in the form of under-voltage relays monitored by residual current has been provided successfully at the weak terminals.

Table 1 Overall Performance of 1Φ arc

System Voltage kV	Review Period (Months)	Total Faults (100 %)	1Φ Trips Required	Successful 1Φ Trips +Arc*	1Φ Arc +3Φ Arc*	1Φ Arc +3Φ Arc +LO*	3Φ Trips for 1Φ Faults	Correct 3Φ Trips	Remarks
400	24	83	50 60 %	27 32,5 %	0 -	1 1 %	23 28 %	32 38,5 %	Table 2
330	12	4	2 50 %	1 25 %	0 0	0 0	1 25 %	2 50 %	
275	48	382	319 83,5 %	296 77,5 %	22 5,8 %	2 0,5 %	31 8,1 %	31 8,1 %	Table 3
220 A	77	319	290 91 %	251 78,7 %	6 2 %	0 0	30 9,4 %	32 10 %	
220 B	24	68	55 80,8 %	42 61,8 %	3 4 %	1 1,5 %	9 13,2 %	13 % 19,1 %	Table 4
132 A	24	?	43 100**	38 88,4**	0 0	0 0	? -	? -	
132 B	69	229	161 70,3 %	131 57,2 %	26 11,4 %	0 0	4 1,7 %	68 29,6 %	
66	24	40	3 7,5 %	3 7,5 %	0 0	0 0	0 0	37 92,5 %	

Arc: Auto Reclosure *: % of Total Faults **: % of 1Φ Faults Only LO: Lockout

Back-up overcurrent relays

During the dead time with one phase open there is a zero sequence current on the system, and in the affected line. This zero sequence current will give an output to the residually connected back-up overcurrent relays which will tend to cause their incorrect operation if the dead time exceeds the relay operating current/time setting. In the limit the residual current can have a magnitude of three times the line load current, as can be seen readily from the sequence connection diagram Fig 3(a), if the negative sequence circuit impedance Z_2 tends to infinity. In this case the entire load current in the sequence networks flows through the zero sequence network and the line residual current is three times this value. To avoid false tripping, care must be taken to ensure that the dead time does not exceed the relay operating time with this current flowing in the residual circuit.

Resetting of faulty phase relay

When correct isolation of the faulty phase has been effected, the voltage on that phase is still low, particularly while the fault arc persists. It will be lower than normal even when the secondary arc has extinguished. The faulty phase relay will still have a residual component of current which can be as high as three times the load current. Thus the relay will tend to remain operated during the entire dead time and the danger exists of a false retrip on reclosure.

The protective scheme must be designed to ensure that no unnecessary trip will occur on reclosure and that developing faults are cleared correctly, blocking the single-phase reclose command and initiating a three-phase trip and reclose instead.

High resistance faults

These can occur on lines due to mid-span flashover to ground caused by grass fires or due to trees blown against the line by gusts of wind. If the supply is over a single line it is desirable that such faults should be cleared on a single-phase basis as several faults can occur in succession and it would be preferable to avoid the supply interruptions which would result if the line were tripped three-phase.

High resistance faults are a problem for distance relays and their phase selectors and supply authorities welcome the new generation of relays which are inherently sensitive and phase selective, such as the recently developed ultra-high speed travelling wave protection [11] or phase comparison operating on a per phase basis; or distance relays having quadrilateral characteristics for greater fault resistance tolerance, combined with ultra-sensitive and selective phase-selector relays.[12]

Where directional comparison earth-fault relaying is used to provide sensitive protection for high resistance faults, cognisance must be taken of the fact that the operation of the line with one phase open will set up zero and negative sequence circulating currents. These can give rise to conditions identical with those for an internal fault on the line and lead to a false three-phase trip during the dead time of the single-phase auto-reclosing.[9]

Phase discrepancy protection

Circuit-breakers with an independent mechanism per phase normally have a phase discrepancy protection to open all three phases if the position of the breaker poles is in disagreement for a certain time. It is important to ensure that the setting of the phase discrepancy time delay relay exceeds the dead time for single-phase reclosing.

Conclusions

Single-phase auto-reclosing can be applied with advantage and little additional cost in the majority of networks of 132 kV and above. It can be used in many circumstances where three-phase reclosing is not permissible and provides an economical means of increasing transmission capacity, network security and continuity of supply without introducing serious disadvantages. With suitable compensation it can also be applied to long transmission lines.

Without single-phase reclosing it would not have been possible to provide single line supplies of acceptable quality in the Republic of South Africa.

APPENDIX 1

Sequence network connections for the open phase conditions

Fig 2(a) shows the equivalent single line diagram of a simple network with an open circuit in one or two phases between the points A and B. Fig 2(b) shows the interconnections between the three sequence network 'boxes' for a single-phase open and Fig 2(c) shows these when two phases are open.

Fig 3 shows the detailed interconnection of sequence impedances which result for these two cases, from which it is clear that for a single open phase the negative and zero sequence networks appear in parallel with each other and the combination is in series with the positive sequence network Fig 3(a). They are all in series when two phases are open Fig 3(b).

For the single-phase open condition, therefore, either the equivalent Z_0 or the Z_2 viewed from the break point, and preferably both, should be low compared with the total positive sequence impedance Z_1 for satisfactory single-phase reclosing. If two phases are open *both* Z_0 *and* Z_2 must be low.

APPENDIX 2

(a) Hydra-Poseidon 400 kV Line: *Particulars*

1 *Line length*	— 294 km
Configuration	— Horizontal
Capacitances:	
R-E 2,6 μf	
W-E 2,34 μf	
B-E 2,6 μf	
R-W 0,431 μf	
W-B 0,431 μf	
B-R 0,1136 μf	
Transpositions	— NIL
2 *Shunt reactor*	
Rating	100 MVAR at 400 kV
Construction	— Shell type
Z_1	= 1 600 ohms/phase
Z_0	= 1 600 ohms/phase
Number installed	= 1

(a) Hydra-Poseidon 400 kV Line: cont

	Particulars
3 *Neutral reactor*	
Inductance	0,56/0,68/0,81 H
Reactance (at 50 Hz)	= 176/214/255 ohms

(b) 330 kV Line:

1 *Line*	
Line length	= 520 km
Configuration	= Triangular
Capacitative susceptances:	
B_1	= 1 873,9 S
B_0	= 1 198 S
Transpositions	= 2
2 *Shunt reactors*	
Rating	70 MVAR at 330 kV
Construction	— Shell type
Z_1	= 1 556 ohms/phase
Z_0	= 1 556 ohms/phase
Number installed	= 3
3 *Neutral reactors*	
Inductance	= 1,59 H
Reactance	= 499 ohms
Number installed	= 3 (Two at one end and one at the other end)

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Exporting technology — CSIR assists Brazil in a lightning research programme

In October 1984 we published a paper presented at our symposium 'Electronics in Mining' by three members of the National Electrical Engineering Research Institute of the CSIR. The article dealt with an improved lightning warning system and had been developed from a programme of lightning research which has gathered information over several years using the lightning tower of the CSIR, Pretoria.

It was therefore heartening but not really with surprise that we learnt that the electricity supply company of the Brazilian state of Minas Gerais had entered into a R450 000 contract with CSIR to supply the design and construction of a lightning research station. Dr Eriksson who was recently elected chairman of the CIGRÉ International Working Group on lightning is the leader of the team on this project and has selected a site for the tower outside the city of Belo Horizonte. The warning system in this instance is being used to bring the research station into a state of readiness to capture and store the characteristics of a lightning strike to the tower. Information as a storm approaches starting at a 20 km radius, then 10 km and finally at 5 km arms the station and finally the cameras and video, which are on koppies some distance from the tower and at right angles to each other, are switched on to capture a visual should a strike be to the tower. At the same time the instrumentation at the base of the tower is energised to capture the wave shape and amplitude of the current.

Much of the unique equipment needed for the project has been constructed by NEERI's Industrial Technology Group, in collaboration with its Power Systems Technology Group. The latter is also serving as consultants in the planning and subsequent implementation of the research programme.

This project is also an example of the CSIR's dynamic interaction with local industry, with Spescom (Pty) Ltd playing a supportive role in the venture. Spescom has designed the computerised data acquisition system, which will enable the station to capture and analyse individual lightning current pulses which can occur in rapid succession.

Fig 2 illustrates how combinations of lightning distance and flashing rate will change the warning level of the warning system and thus of the station. The flash interval scale is adjustable as are the ranges of flash intervals within which the three warning levels will be triggered. Fig 2 corresponds to a setting of 2, 3 and 4 min for the 20, 10 and 5 km range switches. It is further only approximately true, since the warning system decisions are more complex and also take into consideration low activities nearby but simultaneous high activity further away. The warning system has three levels of alarm, any two of which can be selected.

Low and high levels of operation

In the event of an approaching thunderstorm of sufficient intensity the warning system will set the station to low level of operation. Fig 3 illustrates the system status at this level and at the high level — the only difference being the speed of the video cameras which is increased when the warning system detects a higher alarm level.

With all the equipment powered up, the following is recorded on the chart recorder:

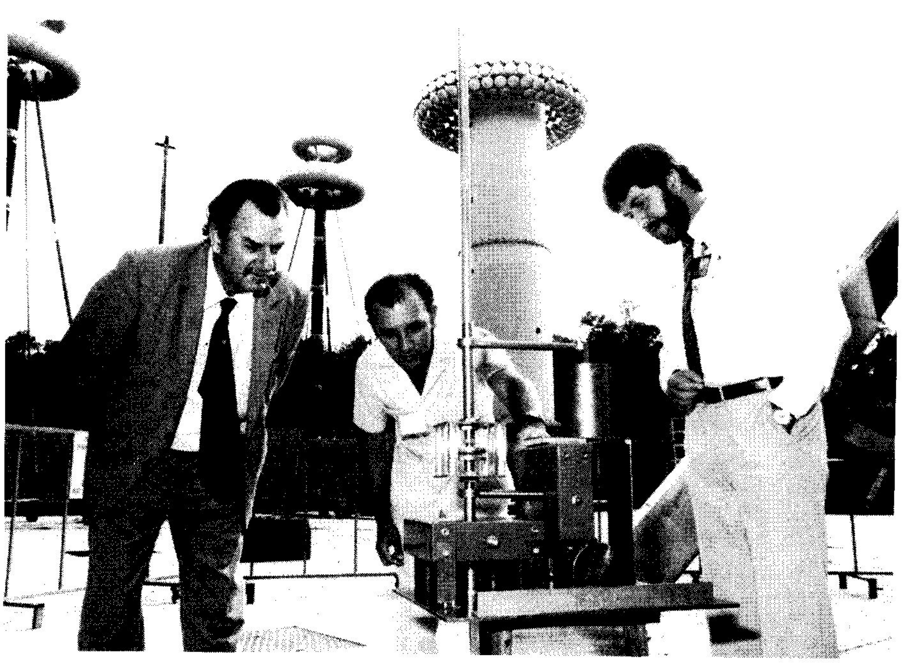
- Lightning ground flashes picked up within the selected range by the warning system. In this system the 10 km range has been selected.
- Lightning strikes to the mast.
- The atmospheric electric field is recorded continuously.
- The status of the station — ie, low or high level of operation.
- Camera advance triggers (override trigger) resulting from a strike to the mast or a ground flash within the selected range, picked up by the warning system. In this system the 5 km range has been selected.

In addition to powering up the equipment the controller also

- Transmits camera override triggers from the warning system or DAS to the cameras.
- Powers up the central camera controller which in turn controls the exposure time of the two cameras.

The data acquisition system (DAS), comprising a trigger unit, two waveform recorders and a computer is powered up, armed and waiting for the signals generated by a lightning flash to the mast.

Incoming signals from a lightning strike are routed to the surge trigger unit and also to the waveform recorders. There



From left: Mr J D N van Wyk (Chief Director NEERI), Mr M Almeida (Divisional Head, CEMIG) and Dr A J Eriksson (Programme Leader, NEERI) seen here viewing the lightning captor for the lightning station in Brazil.

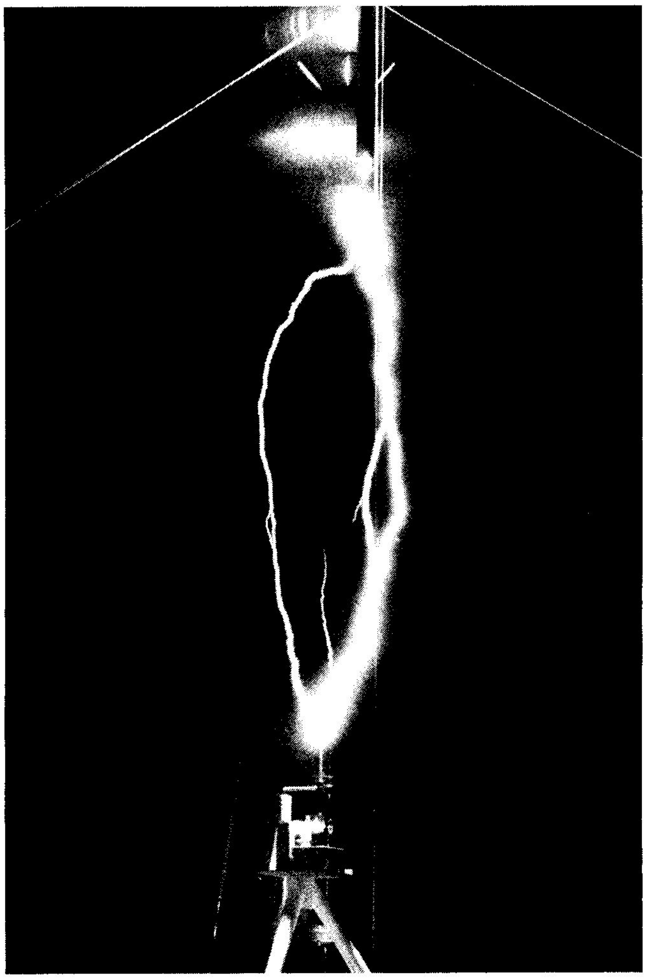


Fig 1 Acceptance tests being carried out on the CEMIG lightning research station.

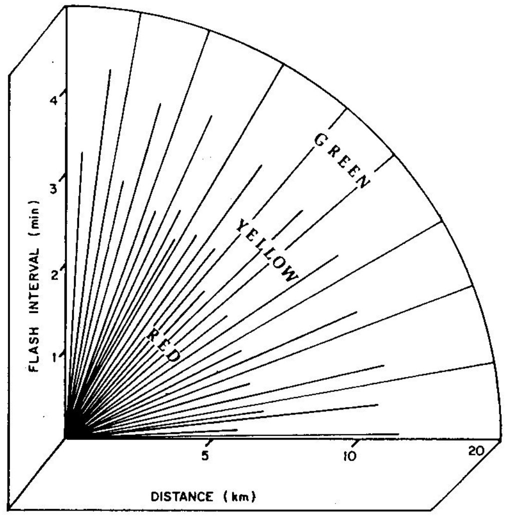


Fig 2 Approximate ranges and flash intervals to trigger warning levels of the warning system.

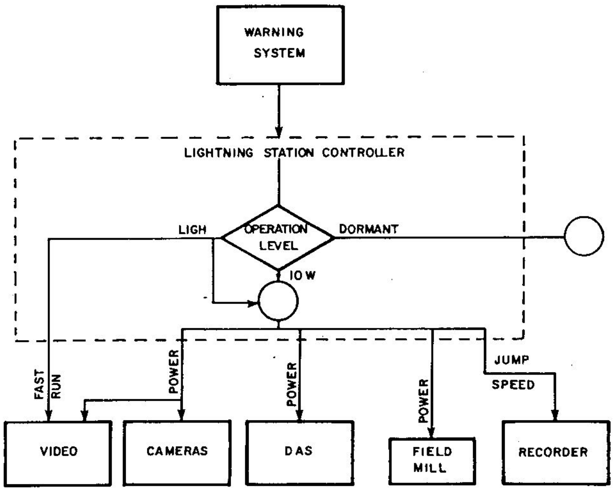


Fig 3 System activities — low and high levels of operation.

are two current transformers, (ie two lightning current signals) and four waveform record channels which can be connected in various ways.

Lightning current capture

In the event of a lightning strike to the mast the surge trigger unit will:

- trigger the waveform recorders (if armed);
- transmit a pulse to the station controller and recorder (via fibre-optic cable) and
- transmit a pulse to the interstroke timing board in the computer.

The computer communicates with the waveform recorders via an IEEE 488 interface and reads the recorder data as soon as a current impulse has been captured.

If, after an initial trigger has occurred, no further triggers occur for a period of one second the computer stores the data on disk and is ready for the next lightning flash.

Returning to the dormant state

When the storm recedes from the station the warning system will change to lower levels of alert, signalling the lowering again of the operation level until the station reverts to the dormant state.

GBJ

Programme for Technological & Engineering Careers

(Formerly Engineering Careers & Education Project)

The first matriculants to emerge from the enrichment schemes run by the Programme for Technological & Engineering Careers (PROTEC) have produced some very encouraging results. Of the first group of 67 students who wrote matric last year, 83 per cent passed and 45 per cent obtained university exemption, with passes in maths and science at the higher grade.

Fifty per cent of PROTEC students obtained the highest marks in their schools and two won Shell Scholarships for post-matric study at a private school. A total of 33 received bursaries for tertiary education or were placed in employment and training positions in engineering.

PROTEC has recently received a contribution of 16 Apple Computer systems for its Resource Centre in Soweto. The Resource Centre comprises a Science Exploratorium, to which AECI contributed funds for setting up the first phase last year, the Computer Learning Centre and a technical/careers library. The Resource Centre helps to overcome the gap in black school laboratory and back-up facilities.

At the end of last year PROTEC's pilot project in Soweto had a total of 267 carefully selected students in Standards 8, 9 and 10. According to Project Director, Ms Lente-Louise Louw, 'they constitute a select, highly motivated and hardworking group; they have become increasingly realistic about career choices available to them as a result of attending our Saturday schools and vacation activities regularly. They are above average in maths, science and problem-solving ability. We are sure that all the students who have participated in our project have had their lives enriched by the experience'.

According to Project Chairman, Cliff McMillan, a Consulting Engineer, PROTEC is a long-term programme and its achievements have much wider parameters than can be measured by exam results.

He maintains that PROTEC has succeeded in mobilising the engineering profession and industry. There is now widespread support for PROTEC, notwithstanding the difficult economic climate. 'Development of human potential from all population groups is a priority which cannot be sacrificed in difficult times', says McMillan. 'Industry's commitment has to go far beyond a non-racial approach in employment practice. Candidates from technologically disadvantaged communities will need positive support from employers during their formative years if they are to achieve their career potential'.

From 1985 PROTEC is to extend its Soweto pilot project to other regions. Initiatives are under way in the East Rand, Sasolburg, Bophuthatswana, Natal and the Western Cape. The ultimate objective is a countrywide non-racial effort.

This is a logical development of the work and research that has been done by PROTEC over the past four years. 'To support these expanding activities we have established a need to raise a minimum of R500 000,' says Cliff McMillan. 'Measured in terms of the benefits and costs per student, PROTEC is an extremely cost-effective way of identifying and developing capable matriculants. The only way to redress the projected manpower shortage is to develop the latent skills in all population groups. We have to address the problem at school level. PROTEC is not a charity but an investment in the future. It is critically important that engineering employers should make the necessary commitment by providing employment, bursaries and training if our efforts are to produce results'.

PROTEC is appealing to individual engineers as well as employers and the private sector at large to come forward and make their contribution to this worthwhile investment in the future.

PROTEC's goals are:

- To contribute towards overcoming the projected shortage of engineering and technically qualified personnel in South Africa.
- To identify, develop and actualise potential in disadvantaged secondary school students who have maths and science ability and an interest in careers in technology and engineering.
- To involve the community, including the public and private sectors, the students themselves, their parents, teachers and other existing organisations in PROTEC's goals and enhance self-help efforts.
- To develop employer attitudes to accept candidates from all population groups.
- To develop the programme into a countrywide effort.

To achieve these goals PROTEC focusses on:

- **Selection** of suitable candidates in the early years of high school.
- **Career Guidance** giving students a perception of the issues relating to career choice and opportunities in technology and engineering.
- **Attitudinal Enrichment and Skills Training** concentrating on personal development and the skills needed for the work culture.
- **Educational Enrichment** for students and teachers particularly to develop their potential in maths, science and functional English.
- **Development** of material and techniques — among them audio-visual material and a Resource Centre including a Science Exploratorium, Computer Learning Centre and technical/careers library.
- **Research and Evaluation** of records to provide feedback for future development.
- **Work Experience/Vacation Employment,** including site and office visits and workshops giving exposure to the 'world of work'.
- **Post-School Support,** including assistance in arranging bursaries, applications for University/Technikon enrolment, employment, training and employer bridging activities.
- **Teacher Upgrading** — training of students' regular school teachers in remedial methods, career guidance, etc.

PROTEC fulfils the above objectives through organising specific programmes such as Saturday School sessions for selected Standard 8, 9 and 10 students and Vacation and Afternoon Programmes, eg, camps, skills training workshops, site and office visits, individual counselling. ■

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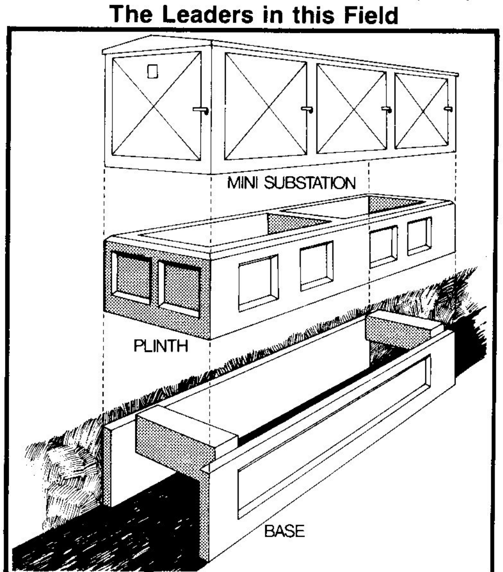

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Teaching robots to see, feel and taste

*Peter Craven

Research aimed at enabling robots to make products as varied as shoes, shirts and lawnmowers as well as assisting in quality control in the foodstuffs industry, is underway at a British university.

The Department of Electronic Engineering at Hull University in northern England has received several large grants to extend its work into robots in industry to enable it complete tasks in inspection and assembly.

The UK Science and Engineering Research Council (SERC) has given R220 000 backing for work on the automation of shirt collar inspection and assembly undertaken by a husband and wife team, Dr Paul and Dr Gaynor Taylor. The two Drs Taylor, both lecturers in the Department of Electronic Engineering, are working on the use of robots to put together shirt collars. Since it is wasteful to detect fabric flaws only after a garment has been made up, the couple is developing a flexible automation system which will identify flaws before assembly, assess whether or not the flaws would spoil the finished garment and finally take appropriate action.

Drs Paul and Gaynor Taylor have also been awarded R92 000 by the SERC for research into robots in the shoe manufacturing industry. They are trying to develop a robot with the ability to see and feel and follow the profiles of different types of lasted shoes, and then looking at the problems in attaching varying soles to appropriate lasted uppers automatically.

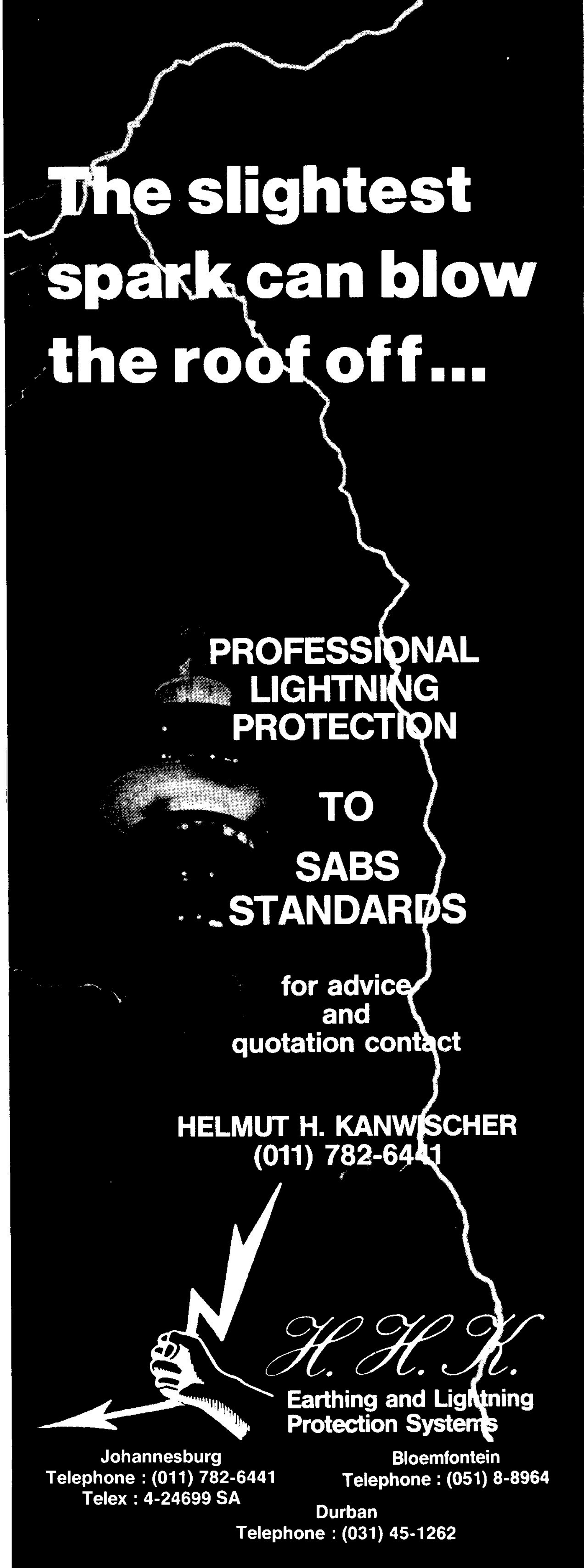
This work is sponsored by SATRA (The Shoe and Allied Trades Research Association) which is concerned that British shoe manufacturing processes take full advantage of new automation. The project has grown out of the final year's work of a student in the Department of Electronic Engineering, Ian Gibson, who graduated last July and is now employed as a research assistant on the project.

Dr Gaynor Taylor has also been given R69 000 SERC backing for a joint project entitled 'Topics in Linear Multi-variable and Multidimensional Systems Theory and Applications'. Dr Taylor and her colleagues are looking at the ideas used successfully in the design of control systems to develop analogous techniques to improve the design of VLSI circuits used, eg in TV games and microprocessors. The work aims to make the testing of components easier and more efficient, and therefore perhaps cheaper.

Another team headed by Mr Klaus Selke, Lecturer in the Hull University electronic engineering department has been awarded R228 000 by the SERC for a project entitled, 'A Knowledge-based Approach to Robotic Assembly'. Normally, robots used in industry are blind to their environment; they can be programmed to move to particular locations, but are unable to make adjustments to take account of errors and unexpected situations. This research aims to equip robots with sensors so that they can re-orientate themselves and deal with minor deviations in position. Dr John Hill and Professor Alan Pugh have also been awarded R180 000 from the SERC for three years of research into quality control by robot sampling in partnership with the Cadbury-Schweppes company.

(University of Hull, Hull, N Humberside, England; Tel: (0482) 4-0311).

*LPS Science Staff



Forum

Sir

Special General Meeting: 28 February 1985

Immediately before the Annual General Meeting and incoming President's Address, the Institute held a Special General Meeting to consider a change to the Constitution.

I believe the wording of the change for consideration was most appropriate, *viz:*

> The Constitution of the Institute in stating the qualifications required for some grades of membership calls for *inter alia* a degree in electrical engineering. Some universities are issuing degree certificates in electronic engineering and while electronic engineering is by definition clearly electrical engineering Council feels that in order to dispel any doubt or confusion that could arise from a too literal interpretation of the Constitution, a definition should be incorporated in the preamble of the Constitution.

However, the proposed amendment to the Constitution resulting from that consideration, albeit such proposal having been seconded and properly voted for, I believe to be most inappropriate. I say this because the wording of the insertion, *viz* 'The term "electrical engineering" shall be deemed to be a collective term applicable to all fields of the discipline in which electrical science is applied *in the service of mankind*' implies that the Institute's membership committee must now consider whether candidates are practising electrical engineering in the service of mankind or not. There are many who possess impeccable education, training, experience and age qualifications for membership of the Institute but whose application of electrical science in the service of mankind is questionable. Thus, the Institute's Membership Committee has to make a moral judgement on the work being done by the applicant and decide, for example whether a candidate's work on gambling or slot machines, missiles or other weapons of mankind's destruction are truly in the service of mankind. I do not believe that is the sort of judgement the Institute should ask of its Council members.

Perhaps the columns of *Elektron* are an appropriate place for this to be discussed further.

ERIC DAVISON, *(Fellow)*

PERSONALITIES

Wits CEE Course

Seen at the Witwatersrand Continuing Engineering Education External Insulation for High Voltage Systems Course held at the University between 18-22 February 1985. From left: Messrs A Bekker, A Britten, J Holtzhauzen, P Lambeth, (Prof) J Reynders and I Jordan.

Mr Lambeth was the lecturer for the course which was reported in last month's issue.

HIG Chairman

If enthusiasm is a criterion then Pieter Man in'T Veld, chairman of the Historical Interest Group comes out way on top.

Born and educated in Holland, Pieter emigrated to South Africa in 1962 to establish and manage the Philips Telecommunications factory. He retired after 38 years' service with Philips as the Group Technical Manager of the SA Philips companies. Perhaps the Wadeville factory can be described as a monument to him.

His membership of societies is impressive. In Holland he is on the founder roll of the Netherlands Professional Engineers (1962) and is a Member of our Institute. Chairman of our Historical Interest Group since 1980, his main drive is the establishment of a Museum of Engineering and we wish him and his committee all success.

GBJ

SOLID STATE PHYSICS AND MATERIALS SCIENCE SPECIALIST GROUP OF THE SOUTH AFRICAN INSTITUTE OF PHYSICS

Awards Programme 1986

This specialist group administers an awards programme designed to reward excellence by young scientists in the field of Solid State Physics and/or Materials Science in South Africa.

The SMM and SAMES awards are aimed specifically at the post-graduate level and judgement is made on the basis of a publication originating from a thesis presented to a South African University. In addition, a prize is awarded annually for the most outstanding essay written by an under-graduate (including honours) student. The prize is open to any student registered at a South African Institute of tertiary education.

Please note that the SMM and SAMES awards are intended for recent graduates and the appropriate degree must have been conferred no more than three years prior to the closing date of application, which is April 1, 1986.

Further information and entry forms may be obtained from the Secretary at the following address:

c/o National Institute for Materials Research
CSIR
PO Box 395
Pretoria 0001
Tel: (012) 86-9211

Institute News

We welcome new members and congratulate those who have received higher status.

New Members

Pinto, Teixeira, Luis Assis Camilo, Electrical Engineer, SABC, Johannesburg.
White, Allen, Engineering Director, GEC Mine Winder Systems, Benoni.

Graduates

Bennett, Michael John, Engineer-in-Training, Electricity Supply Commission, Johannesburg.
Fish, Melville, Engineer-in-Training, ESCOM, Cape Town.
Nothnagel, Heinrich, Student (Stellenbosch), Cape Town.
Van der Merwe, Neville Patrick, Engineer, Posts & Telecommunications, Bloemfontein.

Students

Crichton, Mark Stuart, Student Engineer, SATS, Hilton.
Loubser, Nicolas Johan, Student, Bloubergstrand.
Wilson, Steven Aubrey, Student, Posts & Telecommunications, Windsor Glen.

Transfers to a Higher Grade

Graduates to Members

Almond, Richard Charles, District Eng Elec, SATS, Durban.
Dinkelacker, Andreas Martin, Snr Development Engineer, Telkor Signalling Co (Pty) Ltd, Dawnview.

Students to Graduates

Bil, Ryszard Zbigniew, Designer II, ESD (Pty) Ltd, Roosevelt Park.
Burdes, Jonathan Paul, Engineer-in-Training, ESCOM, Benoni.
Caduri, Amir, Analyst/Programmer (Grade TE3), ISIS (Pty) Ltd, Johannesburg.
Hunter, Stephen John, Engineer-in-Training, ESCOM, Bryanston.
Kaplan, Saul Bernard, National Service 7.1.84, Glenhazel.
Kleyn, David Anthony, MSc Elec Eng Student, Cape Town.
Schronen, Michael Bernard, Asst Engineer, SATS, Stellenbosch.
Sonnabend, Michel Joseph, Engineer, NIAST; CSIR, Pretoria.
Whalley, Mark George, Asst Engineer, SAA, Edenvale.

SACPE and the Institute — do they complement each other or not?

I have on my desk an unsigned, undated letter addressed to the Secretary (*sic*) *Elektron* written on EASA letterhead. It refers to my report 'The Image of the Institute' in *Elektron* September 1984. Now such letters normally go straight to the WPB on my right, but in this instance I cannot let the statements made go unchallenged.

As a recognised society in terms of Act No 81 of 1968, SACPE has accepted our constitution with its engineering corporate membership qualifications as adequate. Let me spell them out to you EASA with the SACPE requirements.

	SAIEE	**SACPE**
Educational qualifications	*Recognised BSc (Elec Eng) or equivalent*	*Recognised BSc (Elec Eng) or other prescribed examination*
Experience/Training	*5 years*	*3 years*
Age	*26 years (min)*	*21 years (min)*
Grandfather clause (older than 50 years and does not hold university degree)	*12 years superior responsibility*	*25 years' experience — 10 years at higher level*

Let us not worry about what happened before the Act at Institute level or even the extended '6 month clause' of SACPE that admitted engineers without qualifications to the professional ranks.

Insofar as being judged by our peers (friends as you put it EASA) you are far off the mark. There is no greater honour than being judged by our equals as deserving recognition. At any rate who sits on the PAC (Electrical) of SACPE but members of the SAIEE and the same exercise and care is taken there as a duplicate of the work done by the SAIEE membership committee. While the registration committee of SACPE has the final rubber stamp so does the Council of the SAIEE. To say, therefore, EASA that the SACPE way is less subjective than the Institute way shows perhaps a lack of the knowledge of the mechanisms involved.

There is no doubt in my mind that we have created a SACPE (which these days is a misnomer) which perhaps unwittingly has reduced and is eroding the status of the learned societies. If the argument is put forward that the Act does not allow societies to be examining bodies then change the Act. At least in the UK the Institutions are given the authority to accredit university curricula for the education of engineers. Here again in South Africa the societies do the work but under the SACPE banner. By all means let SACPE confer the PrEng or Ir as you prefer EASA, but let it be seen as an Institute function to say to SACPE that engineers are worthy of that title. We pay our fees to SACPE so that they can protect the public against us. An odd situation indeed.

GBJ *PrEng*

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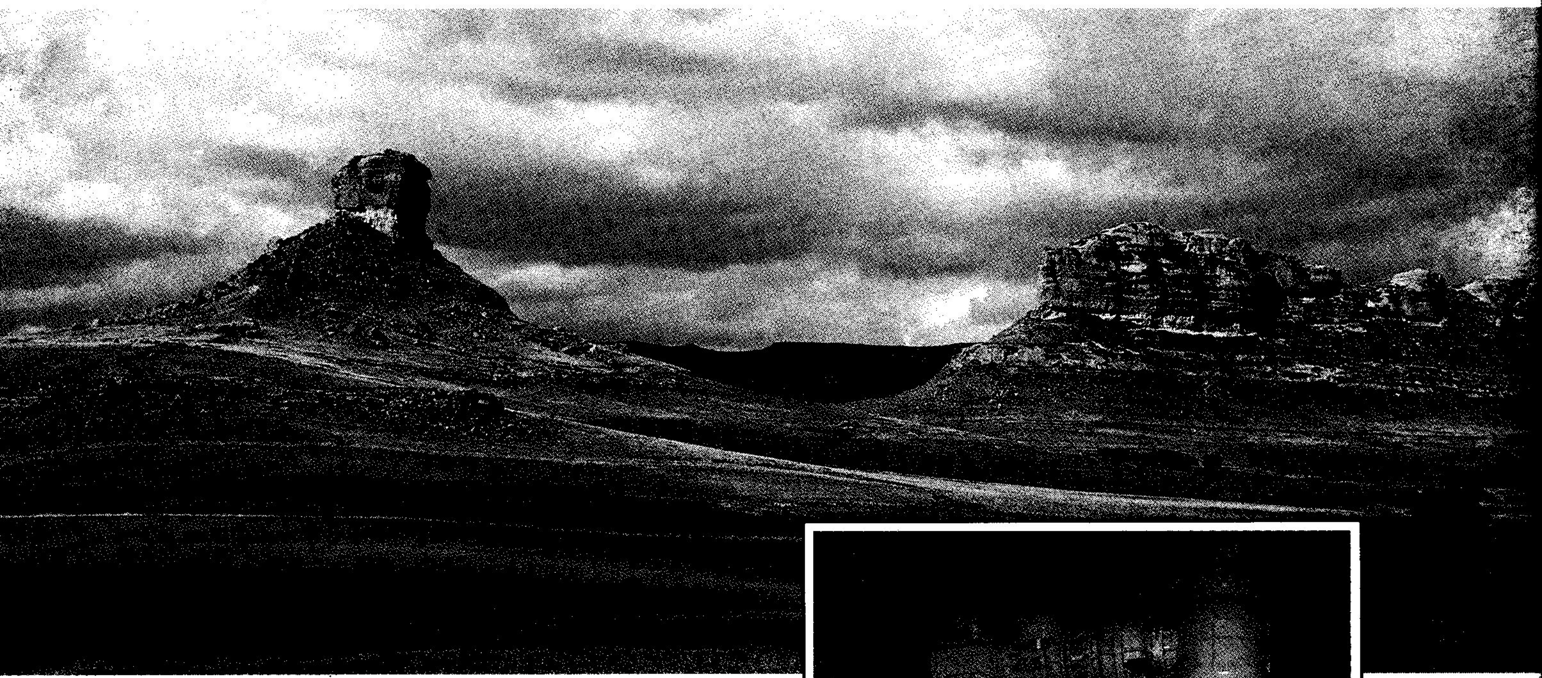
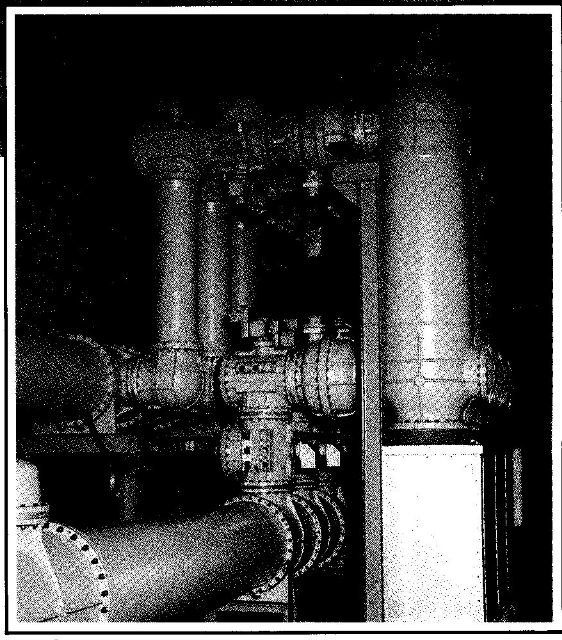


Photo: Publicity and Travel Department: South African Transport Services.



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