PROCEEDINGS AT THE FOUR HUNDRED AND TWENTY-SECOND
GENERAL MEETING

Held at Kelvin House, corner Marshall and Hollard Streets, Johannesburg

Thursday, 29th May 1952

J. T. ALLAN (President) was in the Chair and declared the meeting open at 8 p.m.
There were present 61 members and visitors and the Secretary.

MINUTES

The minutes of the monthly general meeting held on the 24th April 1952, were taken as read and were confirmed.

MEMBERSHIP

THE PRESIDENT announced that in terms of By-Law 5.2.4. the Council had elected the undermentioned candidates to membership of the Institute in the following grades:

Associate Member: DAVID STRATTON DUNCAN.
Transfer from Associate Member to Member: JOHN BROUGHTON HOME-RIGG, KENNETH LEWIS.
Transfer from Student to Associate: ERIC SINCLAIR.

PAPER AND DISCUSSION

N. M. HOOGENHOUT (Associate Member) then presented his paper entitled 'The electrical equipment of the Iscor works at Vanderbijl Park.'

Contributions to the discussion were made by L. L. Brinkworth (Member) and K. D. Starr (Associate Member).

On the proposal of Dr J. H. Dobson (Past President) it was agreed that a letter of appreciation be sent to Dr F. Meyer, Chairman of the South African Iron and Steel Industrial Corporation, Ltd., thanking him for allowing Mr Hoogenhout to present his paper on the Iscor works at Vanderbijl Park before members of the Institute.

There were no contributions under the remaining items on the agenda.

The President declared the meeting closed at 9.40 p.m.
THE ELECTRICAL EQUIPMENT OF THE ISCOR WORKS
AT VANDERBIJL PARK

By N. M. HOOGENHOUT (Associate Member)*

This paper was received 15th April 1952

SUMMARY

The paper describes the main features of the electrical equipment at the recently completed steelworks of the South African Iron and Steel Industrial Corporation at Vanderbijl Park. Many recent developments in the electrical field as applied to steel making and processing have been incorporated in the plant and some of these are described in detail.

CONTENTS

1. INTRODUCTION
2. GENERAL ASPECTS AND SCOPE OF THE WORKS
3. THE MAIN DISTRIBUTION SYSTEM
4. TRANSPORTATION EQUIPMENT
5. METALLURGICAL DEPARTMENT
6. ROLLING MILLS DEPARTMENT
7. ROTATING AMPLIFIERS
8. CONCLUSION

1. INTRODUCTION

The original plant of the South African Iron and Steel Industrial Corporation at Pretoria came into production early in 1934. Numerous extensions have been made to this plant since that date, and its present output is now more than three times the originally planned figure. In 1941, it became apparent that site limitations at Pretoria would hamper further progress and it became necessary to break fresh ground. The new site chosen has since become known as Vanderbijl Park in which the first unit erected was a plate mill which came into production in 1943. Until recently it has been using slabs rolled at Pretoria as its input material.

The electrical installations at the original Pretoria Works and at the Vanderbijl Park plate mill were respectively described in papers read before this Institute by T. P. Stratten in 1934 and C. Drabble in 1946.

In the latter half of 1947, preliminary site work commenced on the building of a complete and fully integrated steelworks at Vanderbijl Park. The first unit came into operation in June 1950, and the whole plant has now been in operation for some time. The purpose of this paper is to describe in general terms what are considered to be the more interesting features of the electrical equipment associated with this new plant.

2. GENERAL ASPECTS AND SCOPE OF THE WORKS

The main producing units at the new works are

(i) a battery of coke ovens together with its by-products plant
(ii) two blast furnaces
(iii) the steel-melting or open-hearth plant
(iv) rolling mills plant comprising ingot-heating furnaces, reversing slabbing mill, plate mill, continuous hot-strip rolling mill, various smaller mills and arrangements for pickling, annealing, galvanising, tinning, etc.

Associated with these main units are an electrically-driven blower installation for the blast furnaces, a boiler house to supply process steam to the various departments, gas-purification and storage equipment, water-storage, circulating and filtration plants and last but not least, the electrical distribution system.

In the main, the electric drives and local distribution equipment formed part of the various main contracts and were erected by the respective contracting firms. All

*Mr Hoogenhout is the Mechanical and Electrical Engineer of the South African Iron and Steel Industrial Corporation, Ltd.
general site distribution work, however, as well as all the electrical installation work in the steel-melting plant and rolling mill divisions was undertaken by the Corporation's electrical staff. The electrical installation in the rolling mills division is of particular interest and some aspects of it will be dealt with in greater detail later in this paper.

From a construction engineer's point of view, many advantages were obtained in the early stages of construction from the fact that railway, water and electric services connected with the plate mill already existed. A great deal of pioneering work was therefore avoided, and as far as electric services were concerned it was a relatively simple matter to supply power from the existing plate-mill system to the various centres of new activity. 11 000/380-volt step-down transformers were used for this purpose and these transformers were later on incorporated in the permanent lighting system.

3. THE MAIN DISTRIBUTION SYSTEM

When it is considered that the total connected horse-power on the whole plant is 120 000 and that the plant itself is spread over an area of approximately one square mile some idea can be formed of the magnitude of this system. Apart from smaller local distribution systems installed by contractors, the Corporation's staff installed 71 000 kVA in transformer capacity 187 miles of paper-insulated cable 79 miles of conduit 131 miles of rubber- and plastic-insulated cable.

Several important considerations had to be taken into account in planning the main distribution system and these will now be dealt with in general terms.

3.1 Demand factor

It is necessary to have a fairly accurate knowledge of the power requirements of a plant long before planning can commence on its distribution system. The power supply authorities have to be consulted and even the final choice of a works site may depend on the magnitude of the expected load.

The terms demand factor, load factor and diversity have fairly well-defined meanings and some handbooks even venture to give values for them in typical instances and for certain industries. When it comes to steelworks, however, there is a striking lack of information even in technical papers.

In the case of Vanderbijl Park, the figure for the one-hourly maximum demand was arrived at partly from information received from the United States, but mainly from previous experience at Pretoria. The figure originally notified to the power supply company was 40 000 kW and this estimate was subsequently increased to 42 000 kW when details of the complete plant became available.

In arriving at this estimate, it had to be borne in mind that the load would arise from the use of electric motors totalling 120 000 h.p. Of this connected motor load only approximately 8 000 h.p. is associated with standby plant. In addition to motor load, approximately 6 000 kVA of transformer capacity for electric furnace heating and 2 000 kVA for lighting had to be brought into the calculations. To add to the complexity of the matter, large numbers of motors, such as those on cranes and mill auxiliaries operate on intermittent duty only. Generally speaking these are one-hour rated machines and their short-time ratings bear little relation to their average duty. Factors like these make it practically impossible to estimate maximum demand with any degree of accuracy from basic data. A thorough study of the problem as applied to steelworks could easily form the subject of a complete paper. As it turns out at Vanderbijl Park, the maximum demands so far experienced are fairly close to the original estimates.

3.2 Provision for future expansion

Once the figure of total maximum demand had been arrived at, it became possible to start the planning of the main incoming substation, the arrangement of which is shown at the top of Fig. 1.

As 40 000 kW is already a fairly high figure for 11-kv switchgear it was decided to adopt a sectionalized double-busbar design. Additional demands of any magnitude will be catered for by additional sections. It is quite possible, of course, that
future demands may grow to a magnitude requiring a separate complete ring system and it was felt that sectionalization was the only way in which provision for such development could be made without undue interference with operating plant.

3.3 Continuity of supply

In any steelworks and particularly in some of the metallurgical processes, power interruptions can quickly give rise not only to serious losses in production but also to damage to plant. It was sought to minimise these dangers as far as possible by adopting a double ring-feed system to all departments where continuity of supply was vital. The diagram of the 11-kV main distribution system shows how this is arranged. Normally both sectionalizing switches and outgoing switches to the ring systems are kept closed. Division of load between the two rings is roughly equalized by the selection of the appropriate busbars to plug into at the different substations. In the event of a complete failure of supply to one busbar at any one of the substations on the ring system, a quick changeover to the other bars can be made without waste of time in examining how the rest of the system is going to be affected by the re-distribution of load. All main substations are nevertheless connected by telephone to facilitate switching operations.

Fig. 2 is a line diagram which has been drawn up to show the type of feeder protection provided for this ring system, and the time settings on the protective relays. Experience so far has shown that this arrangement works very satisfactorily, the main purpose for it, of course, being to isolate only faulty sections of the system.

3.4 Distribution voltages

Power is distributed and used at four different voltages.

The main distribution of power as already mentioned takes place at 11 kV. This was chosen as this voltage was regarded as the highest to which conventional underground cable practice could be applied. Although it leads to somewhat heavy busbars and cables at the main substations it is a voltage which lends itself well to direct application on the larger motors. The blast furnace blower motors and all the big motor-generator sets in the rolling mills operate directly from this supply.

Secondary distribution is done at 3.3 kV and it was laid down as a general rule that all constantly-running machines such as pumps, compressors and fans requiring 100 h.p. or more, should be supplied direct at 3.3 kV. As all sections of the plant do not require this voltage, step-down transformers are provided only at those substations nearest to the plants where it is required. In some of these, local ring feeds have been provided, but the 3.3-kV system is not interconnected throughout the works. To ensure continuity of service it was in this instance found to be more economical to provide duplicate transformers at strategic points.

The voltage selected for smaller a.c. auxiliary drives is 380 volts. As in the case of the 3.3-kV system there is no extensive interconnection between different portions of the works, which are spread over too great an area to make this economical. Continuity of supply is taken care of rather by providing duplicate step-down transformers where necessary. Experience at the Pretoria Works has shown that 380 volts is a very suitable voltage to use where hot and dusty conditions have to be contended with. The somewhat heavier outlay in copper which the choice of this voltage entails is partly offset by limiting the horsepower of motors connected to this supply to 100 h.p. wherever possible.

Direct current at 440 volts is used extensively in all sections of the plant having large numbers of overhead travelling cranes and other intermittent or reversing-duty auxiliaries. Conversion to direct current is by means of banks of pumpless steel-bulb mercury-arc rectifiers situated in those substations nearest to the load. There are three such rectifier installations with a combined capacity of 9,000 kW. Distribution of 440-volt power follows the same lines as those of the 3.3-kV and 380-volt systems.

The 380/220-volt lighting distribution system is entirely separate from the low-voltage power system. Local failures of the power supply, therefore, do not affect the lighting supply. This is an important feature from a safety point of view as nearly all sections of the works operate on a 24-
PROTECTION DIAGRAM OF 11KV RING MAIN

Fig. 2
hour basis. As the lighting system extends over a much greater area than the works system, it was found to be more advantageous to adopt a ring feed system in this instance. All lighting transformers are therefore interconnected throughout the works.

3.5 Underground distribution

All power and lighting distribution and reticulation on the whole works is by means of underground cable.

The main incoming substation has been located as near as possible to the rolling mills which are the biggest power consumers. An underground cable tunnel connects the main substation with the hot- and cold-strip mill substations. Main feeder cables between these substations and others on the ring system are laid in brick trenches covered with reinforced-concrete slabs. Cable routes have been carefully selected to avoid interference as far as possible with future extensions. Cable trenches although responsible for a somewhat heavier initial outlay soon pay for themselves in preventing inadvertent damage to cables, whilst they facilitate repairs and the installation of additional feeders when required.

Another important aspect which will be appreciated by construction engineers more than by anyone else is that all cables which follow the same route need not necessarily be laid at the same time. With deliveries as they are to-day this is an important consideration; moreover, the difficult choice of either re-excavating trenches at frequent intervals or leaving cables exposed to the hazards of construction is avoided. The construction of approximately two miles of brick-lined cable trenches has therefore been regarded as well worth while.

4. Transportation equipment

In all steelworks the transportation of raw and partly-processed materials plays a very important part and the electrical aspects of two of the most important means of transportation are considered worth describing.

4.1 Rail transportation

Although the main producing centres are concentrated in an area approximately one mile square, railway tracks extend over a much wider area from receiving and despatch yards at the one end of the site to slag dumps at the other end. In all there are 60 miles of track on a very level site. Diesel/electric locomotives were selected as the most suitable and economical means of handling rail traffic over this area.

Fig. 3 is a photograph of one of the nine bigger locomotives used. This is a 65-ton...
machine equipped with two 300-h.p. diesel-generator units. It has two traction motors per bogie geared to the axles through double-reduction gears. The traction motors are force ventilated. The maximum speed of 20 m.p.h. and maximum tractive effort of 39000 lb have been found to be admirably suited for heavy hauls from the more outlying portions of the works.

For shorter internal hauls, seven 35-ton locomotives are used. These are each equipped with one 300-h.p. diesel-generator unit. Generating and tractive equipment are interchangeable with the larger units.

The time required for overhaul is reduced to a minimum by having spare generating units and bogies available. The old ones are removed bodily from the locomotive and replaced by fresh ones which have been previously attended to in the workshops.

During the construction period before permanent d.c. supplies had been provided to all sections it was quite a common sight to see one of these locomotives drawn up next to a crane gantry where it served as a temporary power station supplying power to overhead travelling cranes engaged on erection work.

All locomotives are equipped with two-way wireless-telephone communication and are thus in constant touch with the central traffic control office from where drivers receive their instructions. There was some doubt whether this form of communication on very high frequency would be effective when locomotives were shielded by or operating inside large iron buildings. Tests conducted prior to the adoption of the system, however, showed that these doubts were unfounded. The equipment operates on the amplitude-modulation principle at approximately 150 megacycles per second and practically no difficulty is experienced from shielding.

4.2 Overhead travelling cranes

It has been estimated that in the conventional processes of steel manufacture for every ton of finished material finally loaded into trucks for despatch, approximately fifteen tons of material have to be handled by crane through the various stages of manufacture. This figure errs on the conservative side and is considerably higher in less modern plants; moreover, it includes only the handling of raw and partly-processed materials. Other uses of overhead cranes in ancillary services and in maintenance work, roll changing and scrap handling are not included. It is felt, however, that this figure is impressive enough to indicate how important is the role played by cranes in the steel industry. This fact is now fully recognized by manufacturers and users. Within the last ten years or so, most overseas countries have introduced special standards applicable exclusively to the mechanical and electrical design of steel-works cranes. It goes without saying that these standards are stricter and call for heavier duty than any other crane specifications.

Totally-enclosed mill-type motors and dust-proof contactor gear are regarded as essential in the production departments. The largest cranes at the Vanderbijl Park Works are two hot-metal casting cranes each with a lifting capacity of 250 short tons on the main hooks.

Fig. 4 shows these two cranes on their gantry in the final stages of erection. The driver's control cabin can be seen at the lower end of the structure at the right. Above the cabins are the contactor-control rooms. As these cranes operate under dusty and hot conditions the driver's cabin is fitted with a small air-conditioning unit, while the control rooms are heat insulated and positively ventilated with filtered air. These principles have also been applied to other cranes in the steel-melting plant, stripping bay and soaking pit bay where similar conditions of dust and heat are encountered.

Of the total number of 48 overhead travelling cranes operating at Vanderbijl Park, 42 operate on 440 volts direct current. All cranes handling hot metal and the majority of cranes in the rolling mills fall in this category. In spite of many advances made in the direction of fine control on cranes operating on alternating-current supplies, direct current still holds the field where extreme accuracy of control, such as in the case of casting cranes, is essential. It would in fact appear that further improvements in this field lie in the direction of Ward Leonard control in conjunction with rotary amplifiers.
5. METALLURGICAL DEPARTMENT

The majority of electrical applications in this department are entirely conventional and do not warrant description. Two interesting applications, namely the automatic blast-furnace control and electrostatic gas-cleaning plant are similar in principle to those at Pretoria and have been previously described. Under this heading only two applications will be briefly dealt with.

5.1 Electrostatic tar-fog extraction

The gas produced at the coke oven battery carries with it in suspension a very fine fog of tar particles. These minute particles of tar, although they have no detrimental effect on the coke-oven gas as a fuel, have a great nuisance value in that they settle out in pipelines, on valve stems and booster blades and generally have the effect of 'gumming up the works.' It is therefore important to remove them at an early stage, as the effect of tar fouling leads to unnecessary maintenance work from the by-products plant onwards to every section where coke-oven gas is used.

The electrostatic precipitators consist essentially of a nest of vertical tubes through which corrosion-resistant alloy-steel wires are concentrically suspended. These wires hang from a frame which in turn is suspended from one massive insulator which is mounted at the top of a vessel enclosing the whole assembly. This vessel is earthed and connected to the positive pole of a high-voltage direct-current source. The negative pole is carried in a single-core armoured cable to the insulator stem. Gas flows upwards through the tubes in which the tar-fog particles become charged and repelled to the walls of the tubes. Here they collect and finally drip to the bottom of the vessel where liquid tar is extracted.
The direct current is obtained from banks of selenium rectifiers connected in a voltage-doubling circuit. The rectifiers together with step-up transformer, condenser and series resistance are all enclosed in one oil-filled transformer tank and form a very compact unit. Each unit is capable of a maximum output of 120 milliamperes at 33 000 volts. There are two such units each associated with an extractor vessel and capable of dealing with 540 000 cu. ft. of gas per hour. Tar extraction with both vessels operating in parallel is better than 99.5 per cent.

These units require very little attention. The main precautions to be taken are to ensure that tar does not condense on the insulator surface. To prevent this the insulator is surrounded by steam coils and hand holes for periodic cleaning.

As prolonged tracking on the insulator surface can cause permanent damage to it, an alarm circuit is incorporated to give warning of any unusual electrical conditions.

5.2 Blast furnace blowers

Fig. 5 is a view inside the blower house which houses three electrically-driven blowers for supplying blast air to the furnaces. One machine is kept as standby. The air-discharge mains are so arranged that any blower can be used to supply air to either of the two blast furnaces.

These blowers are each capable of a maximum delivery of 68 400 c.f.m. of free air at 20 lb/sq. in. or 52 000 c.f.m. at 26 lb/sq. in. and are driven by 7 000-h.p. synchronous motors which are direct coupled to them through flexible claw-type couplings. Starting is by means of a 3.3-kV pony motor rated at 1 700 h.p. which runs the machine up from rest before the 11-kV supply is switched on to the main motor. The starting operation is automatic from the point where the pony motor is switched in. The electrodes of its liquid starter are controlled by a small motor. When it has run the machine up as far as it is able—to within 98 or 99 per cent of synchronous speed—and provided the exciter voltage has also built up, the 11-kV supply is switched on to the main motor stator through a starting reactor. Shortly thereafter the starting reactor is short circuited and excitation applied to the rotor. A few seconds after the main motor has pulled into step a relay trips out the pony motor.
These machines are provided with kVA regulators which are rendered inoperative during the starting operation but in normal operation are set to maintaining a constant leading kVAR of 2 150 from no load to full load.

6. ROLLING MILLS DEPARTMENT

In this department steel ingots received from the metallurgical side are in successive stages reduced to their final form. At Vanderbijl Park Works, only flat steel products are produced and the first rolling process after the ingots have been reheated takes place in the slabbing mill.

6.1 Slabbing mill drive

The slabbing mill is of the "two-high" reversing type. Ingots of a maximum weight of 15 tons are reduced to thicknesses varying from 12 inches to 3 inches in this mill. Both the thicknesses to which they are reduced and the lengths into which the slabs are sheared at the end of this rolling process are determined by the further processing for which they are intended.

A reversing motor drives the rolls of this mill through a pinion stand. Its main characteristics and those of the flywheel motor-generator set associated with it, are:

**Mill motor**

- Peak output—23 000 h.p.
- Rating (r.m.s.)—7 300 h.p.
- Speed range—0-54 r.p.m. by varying the applied voltage; 54-120 r.p.m. by field weakening
- Time of reversal from +54 to -54 r.p.m.
  -2½ sec
- Maximum cut-out torque—220 000 lb. ft.
- Weight including bedplate—220 long tons.

**Flywheel motor-generator set**

- Driving motor (a.c.)—11-kV, slipring, induction type
- Motor output—5 000 h.p.
- Speed—600 r.p.m. (syn)
- Flywheel — 62 tons. Steel plate construction
- Generators (d.c.)—4 generators each rated 1 450 kW r.m.s., 4 680 kW peak.

The mill motor is of the double-armature two-bearing type, the two armatures are arranged back to back and bolted together by means of a very heavy flanged and spigotted coupling. The power is transmitted through keys on the faces of this coupling.

The choice of a double-armature machine was determined firstly by the practical impossibility of building a single armature of the required output which would be able to pass the South African Railways loading gauge. However, the design affords several other advantages of which the following are the most important:

(i) The diameter of the whole rotor, and therefore its moment of inertia, is smaller than would be the case with a single-armature design. This is of great importance in reversing mill motors which are required to reverse from full speed in one direction to full speed in the other in a matter of seconds.

(ii) Commutator turning or dressing is easily carried out by simply removing the connections to each armature in turn, and spinning the rotor with the other. With a single-armature machine special turning equipment would have to be provided.

(iii) The manufacturer is able to apply full-load tests by the Hopkinson method.

A comparison of the details relating to this drive with details previously published in papers describing the Pretoria reversing mills and the plate mill at Vanderbijl Park will show that all the variable-voltage generators and the plate-mill and slabbing-mill motors are similar. They were, in fact, all supplied by the same manufacturer and all their armatures are interchangeable. There are in all nineteen similar variable-voltage generators in service at Pretoria and Vanderbijl Park. One spare armature is kept at each works. Similarly there are three identical double-armature mill motors in service, one at Pretoria and two at Vanderbijl Park. A spare half rotor is kept available for use at each works. In spite of the very severe duty expected of these machines the need to change armatures seldom arises. The spares are regarded rather in the light of an insurance, as extensive damage or an accident to one of these big machines could quite conceivably put a stop to production for months on end.
6.2 Continuous hot-strip-mill drive

The first processes in this section are to reheat slabs produced in the slabbing mill and then to reduce them in the plate mill to long plates of appropriate thickness and width. From here the plates, still in red-hot condition, pass to the continuous hot-strip mill where they can be reduced to a minimum thickness of 18 gauge. Depending on what further processing is required the strip is either rolled up into coils at the far end of the mill or cut up into suitable lengths by a 'flying shear.'

The hot-strip mill proper consists of six 'four-high' mill stands arranged in tandem. Each mill stand is coupled to its own driving motor through pinion stands and suitable reduction gears.

Fig. 6 is a general view of the mill stands, and Fig. 7 is a view inside the motor house. The driving motors are shown on the right-hand side of the photograph.

Table I has been drawn up to show the horsepowers and speed ranges of the driving motors and a typical load condition. This condition would represent the rolling of a continuous strip weighing approximately 6 tons. During its passage there would be a peak load period of approximately one minute when all six motors are under load. When it is considered that the duration and frequency of these peaks depend on such factors as temperature, gauge, width, weight and the rate at which input material is fed to the mill, one of the difficulties of estimating maximum demands will be appreciated.

The power for driving the hot-strip mill is obtained from two 10,000-h.p. synchronous-motor-driven m.g. sets each having two 700-volt generators all feeding a common bus from which the six mill motors are supplied. As will be explained in greater detail later, the generator voltage can be varied by the use of a motor-operated rheostat in the pattern field of a rotating regulator, while the speeds of individual motors can be set by motor-operated rheostats and vernier rheostats located in the motor fields. Each motor and generator is provided with two d.c. circuit-breakers equipped with magnetic overcurrent releases.

An interesting feature of the 10,000-h.p. synchronous motors may be mentioned here. These machines run at 375 r.p.m. Their stators were too big to pass the railway loading gauge, and were therefore shipped in halves, completely wound at the factory, and then assembled in the motor house at the factory. The stator coils were split, which was vertical to the centre line in this instance. The missing coils were inserted and connected up on site.

<table>
<thead>
<tr>
<th>Mill stand number</th>
<th>Rated horsepower of driving motor</th>
<th>Speed range of motor r.p.m.</th>
<th>Speed range of rolls r.p.m.</th>
<th>Typical load with input material 0.85 inches thick and 50 inches wide</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Horsepower</td>
<td>Motor speed r.p.m.</td>
<td>Strip speed at exit f.p.m.</td>
<td>Thickness at exit inches</td>
</tr>
<tr>
<td>1</td>
<td>3500</td>
<td>300</td>
<td>235</td>
<td>0.510</td>
</tr>
<tr>
<td>2</td>
<td>3500</td>
<td>350</td>
<td>275</td>
<td>0.330</td>
</tr>
<tr>
<td>3</td>
<td>3500</td>
<td>350</td>
<td>221</td>
<td>0.220</td>
</tr>
<tr>
<td>4</td>
<td>3500</td>
<td>350</td>
<td>221</td>
<td>0.220</td>
</tr>
<tr>
<td>5</td>
<td>3500</td>
<td>275</td>
<td>225</td>
<td>0.175</td>
</tr>
<tr>
<td>6</td>
<td>3000</td>
<td>198</td>
<td>225</td>
<td>0.140</td>
</tr>
</tbody>
</table>

Every effort has been made to guard against any electrical trouble which may develop and the interlocking provided eliminates the possibility of incorrect operation. The motor circuit-breakers cannot be closed if there is voltage on the busbars, or if the motor concerned is still rotating after a trip out. Normal field loss and overspeed protection is incorporated. No generator can be connected to the bus while it is generating voltage or
if the busbar is alive. The generators are also protected against overvoltage. All circuit-breakers are fitted with anti-pumping control which allows them to close once only if the control switches are held in the ‘close’ position, and are provided with permissive switches in the motor room so that the attendant can switch off if trouble develops.

To facilitate the work of maintenance personnel the electrical control on each stand is provided with a fault-finding device, which enables the engineers to locate rapidly an open contact in the protective circuit.

stands. Fig. 8 shows the control desk in the control room overlooking the mill.

Under certain rolling conditions, it is deemed advisable to maintain a certain tension between mill stands and for this purpose loopers are incorporated. These consist of an arm hinged at one end and carrying a roller on the other which lifts out of the table between the stands and exerts an upward pressure on the strip. These loopers are driven by d.c. motors which operate under stalled conditions and the loopers can be made to operate automatically by a load relay located in the circuit of the stand following the looper.

Should a cobble occur in a stand the breakers trip and the motor affected is brought to rest by dynamic braking. An emergency stop is also provided which stops the whole mill on regeneration followed by dynamic braking.

Once the individual mill speeds have been set for a desired rolling schedule, the mill control requires very little supervision and it is well within the capability of two men to perform the minor speed adjustments that are necessary on the six mill

6.2.1 Hot-strip mill flying shear

Immediately following the last mill stand is a flying shear consisting essentially of two rotating drums, arranged one above the other and carrying shear blades let into the drums which are rigidly geared together in the ratio of 3 to 2. At every second revolution of the bottom drum the shear blades meet to make a cut. The control of the 900-h.p. motor, which drives these drums, is so arranged that by varying its
speed with respect to the last mill stand it is possible to cut the strip as it issues from the mill into lengths ranging from 16 to 33 feet. In order to ensure that the strip is cut up into equal lengths very accurate speed matching between the shear and final mill motor is required. This is achieved by means of an electronic amplifier acting on the exciter of a separate motor-generator set which supplies only the shear motor. So shown as the one nearest the camera in Fig. 7.

6.2.2 Hot-strip mill runout table

Fig. 9 shows a portion of the runout table at the exit end of the hot-strip mill. Each of the 232 rollers in this table is driven by a 4-h.p. shunt motor. The motors are connected in groups and each group is

effective is this speed matching that lengths cut off by the flying shear do not deviate from the set value by more than 0.5 per cent. In cases where the strip is required in coil form it is necessary only to crop the front and tail ends of the strip. In this sequence the shear starts, makes one cut, stops, and as the tail end of the strip leaves the mill, repeats the operation.

An interesting feature of the shear drive is the high acceleration and deceleration which are necessary for successful operation. The motor accelerates from rest to 300 r.p.m. in 8 to 12 revolutions and deceleration is accomplished in 3 revolutions. As would be expected the inertia of the motor is kept low by making the armature long and of small diameter. The motor is clearly controlled by its own generator. Any variations in the peripheral speed of the rollers caused by variations in the supply voltage or by the load on the rollers would have the effect of causing ripples and consequent cobbling of the strip. It is therefore important to keep the peripheral speed accurately matched with the exit speed of the mill. This is again achieved by means of rotating amplifiers which receive their intelligence from a tachometer generator coupled to the drive of the last mill stand.

The motors driving the strip coilers at the far end of the runout table are controlled in a similar way.
6.2.3 Intercommunication system

All the interdependent operations of the hot-strip mill extend from the slab-re-heating furnace at one end of a 1 200 ft.-long bay to the strip coilers and pilers at the other end. In order that all operators at the different control stations shall be in constant touch with each other they have been provided with a loud-speaking intercommunication system. Such a loudspeaking unit which consists of a small loudspeaker and microphone can be seen mounted over the control pulpit in Fig. 8. Anything spoken into a microphone at any of the control stations is audible to the other operators, and they are therefore able to undertake whatever steps are necessary to ensure smooth running of the whole unit.

6.3 Continuous cold-strip mill

A further reduction in the thickness of hot-rolled strip is necessary for the production of such commodities as galvanized iron and tinplate. This reduction takes place in the continuous cold-strip mill. The input material in this case consists of coils of hot-rolled strip which have been first pickled in a continuous acid-pickling bath to remove all scale.

The maximum weight of a coil delivered to this mill is 15 tons and it generally consists of two or more hot-mill coils butt welded together in one of the processes associated with continuous-pickling unit.

The cold-strip mill consists of four, four-high mill stands arranged in tandem. Each mill stand is driven by its own motor and reduction gear in exactly the same manner as in the case of the hot-strip mill. Only one 10 000-h.p. motor-generator is used in this case, however, and up to a point the control of the main driving motors follows the same lines. As the material passes through this mill in a cold state accurate speed matching is required to avoid tearing or cobbled and is even more important than in the case of the hot-strip mill. Four rotating amplifiers are used for this purpose and they are arranged in such a way that each matches the speed of the motor which it controls to a master reference. A change in the master reference causes a proportionate change in the speed of all the motors simultaneously, but not in the ratios between their individual speeds. The procedure here is to stop the mill after the passage of a complete coil and to thread a new coil through the mill by inching the mill motors until a few turns at the head of the strip have been taken up on a coiling drum at the exit end of the mill. All motors are then speeded up in unison and under load. The process of threading the strip and doing the finer speed adjustments is in the hands of attendants who are stationed on the mill floor next to the mill stands where each has a pushbutton control station. The fine speed adjustments operate on the shunt fields of the individual mill motors and have the effect of changing the speed ratio between the motors. Whatever the new ratio might be, that new ratio is then maintained by the automatic speed-matching equipment. A thickness gauge operating on the strip at the exit end of the mill continuously indicates to the attendants on a centre-zero meter any deviations from the desired thickness. One of their duties is to adjust the mill screw-downs to maintain a uniform gauge and generally speaking, each such adjustment brings with it a new setting for the speed ratios.

Of all the units at Vanderbijl Park this mill is probably the best example of modern pushbutton control. Without going into details it may be mentioned that no less than twelve rotating amplifiers are used in various different applications on this mill alone.

6.4 Electrostatic air filters

It is now almost universal practice to provide filtered air to motor houses, both for cooling purposes and to reduce the maintenance costs and the possibility of insulation breakdown. The atmosphere in steel plants is necessarily dusty and a great proportion of the contamination, particularly in the vicinity of the rolling mills, consists of very fine iron-oxide dust. The air filters chosen for the rolling-mills motor house are of the electrostatic type as these were considered to be more effective than other types in the removal of very fine dust and fumes. These filters are built in separate sheet-iron cubicles each capable of handling 15 000 cubic feet of air per minute. The slabbing mill and cold-strip mill motor houses are each served by a bank of sixteen
such cubicles and the hot-strip mill motor house by two banks of sixteen. Each bank has an intake stack approximately 60 ft high. Fig. 10 is a view of the hot-strip mill air-filtration plant with its two intake stacks.

Each cubicle consists of louvre doors where the air is drawn in, ionizer wires charged at 13 kV d.c. which charge the particles carried in with the air, and a series button which starts a 'wash cycle.' The louvre doors of the cubicle close, the high voltage is removed and a spray header driven by a worm shaft traverses the width of the cubicle spraying the plates with hot water and removing the dirt and the adhesive which run off to a drain. The cubicle is allowed to drain for ten or fifteen minutes when the header starts on its return motion and sprays the plates with fresh adhesive.

![Image of cubicles](image)

**Fig. 10**

of parallel plates connected alternately at earth potential and 6 kV d.c. above earth which collect the charged particles. The efficiency of the system is greatly increased by spraying these collector plates with an adhesive oil which traps the deposited particles. After passing these plates, the air passes through blow-off filters, which trap any large accumulations of dirt which happen to be blown off the collector plates, and then through the fans to the motor-room basement.

The high-voltage d.c. required for the ionizer wires and collector plates is provided by glass-bulb thermionic rectifiers.

When a cubicle has been in operation for 8 to 12 hours, and it is desired to remove the accumulated dirt, the operator presses a

The adhesive is allowed to dry for fifty or sixty minutes when the louvre doors open and high voltage is again applied. The cubicle is then back in service. The whole of the operation described is automatic and requires an operator only to initiate it. One control panel serves the whole bank of cubicles allowing one at a time to be washed.

7. **ROTATING AMPLIFIERS**

In some of the foregoing descriptions mention has been made of the application of these versatile and useful machines. They are extensively used in several of their many applications at Vanderbijl Park and as they are a fairly recent development it has been thought desirable to describe a
few of these applications in some detail. Several different trade names such as Rototrol, Amplidyne, Magnavolt exciter, etc., have been used by different manufacturers to describe machines of this class. Those in use at Vanderbijl Park are of the type using a separate field winding for self excitation. Several others of the type

employing the cross-field principle for self excitation are in use on a new continuous-rod mill at Pretoria. All are essentially specially-constructed direct-current generators capable of amplifying low power supplied from an external source to their field system. They are used in loop circuits to control such electrical quantities as voltage or current, or such mechanical quantities as can be converted into an electrical signal, e.g. speed, torque and tension. Fig. 11 shows a number of these machines installed in the cold-mill motor house.

7.1 Principles of operation

Fig. 12 shows an elementary rotating-amplifier circuit with self-energizing field, tuning resistance and load. On the same diagram is shown the open-circuit magnetization curve which gives one relation between the field ampere turns and the output voltage. Another relation can be obtained in terms of the total resistance of the armature circuit in the form of a resistance line whose slope will depend on this resistance. By varying the tuning resistance it is possible to make this line

coincide very nearly with the open-circuit magnetization line. Under such a condition the amplifier is spoken of as being 'tuned.' The figure shows an approach to such a condition and it will be apparent that in order to get the machine to build up to voltage $V$, only the addition of the extra m.m.f. represented by $AB$ will need to be added to the field system.

The ampere turns ratio $OB/AB$ may be regarded as the 'amplification' of the rotating amplifier and becomes greater the more closely the resistance line is tuned to coincide with the magnetization curve.

In practice the extra m.m.f. is provided by one or more additional field windings in the machine. These windings may be connected in many different ways to pick up and use the signals they receive for control purposes. A few of such applications will now be examined.
7.2 Rotating amplifier for constant-voltage control

Fig. 13 shows how the machine would be connected to keep the output voltage of a generator constant. Two control fields are shown, the one being a pattern or reference field and the other a voltage field. The arrows show the polarities of the three fields concerned. Assume that the generator is running without any pattern field being applied to the rotating amplifier and that this field is then suddenly applied. The output voltage will rise very rapidly, the series-field ampere turns adding to the pattern-field ampere turns. The generator voltage will build up and the voltage field will be excited in such a direction as to buck the pattern field. Since the amplifier is to a large extent self-excited, it requires very little additional energy from its control fields to maintain a particular output voltage. Stability will be reached when the voltage-field ampere turns balance the pattern-field ampere turns.

Assume now that load is applied to the generator causing its voltage to drop. The voltage-field ampere turns will decrease and the amplifier output and therefore its series-field current will increase until the pattern-field and voltage-field ampere turns again balance. Since the strength of the pattern field has remained unaltered the generator output voltage will return to the desired value dictated by this field.

In order to soften the forcing effect of the control fields a so-called ‘anti-hunt’ field—shown dotted in Fig. 13—is often incorporated. This field is connected so as to buck approximately 20 per cent of the series-field ampere turns, and because of its quicker response it tends to reduce the forcing action. The resistance in series with the ‘anti-hunt’ field is set before the amplifier is tuned.

It will be readily seen that all that is required to start up the motors connected to generators controlled in the manner just
This portion of the control in itself would be adequate were it not for the fact that the diameter of the coil being paid off steadily diminishes, and requires a corresponding gradual increase in the speed of the pay-off reel motor. The final value of this speed is approximately three times as high as the initial. The output voltage of the booster, which is quite a small machine, is therefore applied to the voltage field of a rotating amplifier and is connected to buck a constant-voltage reference or pattern field in much the same way as in the application for constant-voltage control. In this case, however, the output from the amplifier is applied to the reel motor shunt-field circuit in such a direction as to weaken this field and increase the speed of the reel motor. In this way there is a continuous effect of restoring the voltage across the booster terminals to a fixed value. As the amplifier is deliberately made sluggish the booster takes the first quick but limited, corrective action, while the amplifier always but more gradually restores its voltage output to a mean value in its operating range.

The object of the rectifier in the amplifier rotor circuit is to prevent a return path for the field current which would cause a loss of field and consequent running away of the reel motor.

One interesting feature of the electronic loop-control unit may be mentioned. The light source consists of fluorescent tubes. The signals from the photocells are fed to the amplifier through a circuit which is receptive only to intermittent impulses with a frequency of about 100 cycles per second, corresponding to the flicker of the fluorescent tubes. Thus any spurious light such as reflected sunlight or a carelessly placed handlamp or torch will not be able to interfere with the operation of the unit.

7.4 Constructional features and maintenance

Although the rotating amplifier is essentially a d.c. exciter, it has certain features which are distinctive. To obtain quick response it is necessary to keep the time constants of the reference fields as low as possible. This is done by laminating the frames and inserting paper between the laminations. The machines have large air gaps to obtain a magnetization curve which is straight over the operating voltage range.
The machines installed at Vanderbijl Park have given very little trouble since they were commissioned. It has, however, been found that some have been inclined to go slightly off tune with the changes in temperature between summer and winter.

8. CONCLUSION

Many of the processes at Vanderbijl Park have no counterpart at Pretoria and this applies also to the electrical installations, particularly in the field of electrical control. For this reason the Corporation again applied the policy which was so successful in the early days of Iscor of sending engineers overseas to make intensive studies in their particular fields of the necessary techniques connected with the production of flat steel products. The electrical side was not overlooked. With the constantly increasing complexity of electrical equipment the days when maintenance and fault finding in an industrial plant can be left to the electricians in charge seem to have passed. A small section headed by an electrical test engineer has been created. It is the duty of the highly specialized men in this section to know exactly what happens when a push-button or control switch is operated, and to assist the men on duty in locating any faults that may have occurred in the often very complicated sequences that follow.

It is hoped that the necessarily brief and often incomplete descriptions which have been given of the electrical equipment at Vanderbijl Park will at least have given some idea of the size and complexity of the undertaking. Naturally a tremendous effort on the part of manufacturers, contractors and of the Corporation’s own staff went into the successful completion of the task. While it is not possible to name them individually this is perhaps a fitting opportunity to thank them all for their efforts which had often to be undertaken under great difficulties.

The writer would like to express his particular gratitude to all the members of the electrical staff who worked unceasingly to bring this work to a successful conclusion.

Finally the writer wishes to record his sincere thanks to those men on the staff who assisted in the preparation of this paper and to the South African Iron & Steel Industrial Corporation for permission to present it before the Institute.

DISCUSSION

L. L. BRINKWORTH (Member): I should like to compliment the author on his well-balanced paper wherein is condensed a review of the magnitude and complexity of one of the most modern steelworks in the world. In addition, the author has described many interesting features associated with electrical equipment.

It is interesting to note the comparatively large capacity of pumpless steel-bulb mercury-arc rectifiers that have been installed purely for providing power for 440-volt d.c. auxiliary services, and that nearly 90 per cent of the cranes are operated on d.c. rather than a.c. This shows that where nicety of control is required the more expensive direct-current drive still leads the field as there is little to choose in maintenance costs between a.c. and d.c. equipment provided this is designed for steelworks service.

A good example of this is given by two of the largest travelling cranes in Southern Africa installed at these works. These cranes, being the 250-ton cranes mentioned by the author, have in addition two auxiliary lifts of 50-ton and 20-ton capacity respectively. There are eight d.c. driving motors per crane to control hoisting and long and cross travelling, and the machines range in size from 150 h.p. to 25 h.p. with a combined total of 875 h.p. per crane.

I think Iscor were wise in using underground cable throughout the works and not attempting overhead reticulation as is sometimes done in the United States of America. I have known of cases in America where even heavy, low-voltage cables have been carried overhead. The adoption of cable tunnels and brick-lined trenches is to be commended in a large works, as additional cables for future extensions can be accommodated very easily without incurring risk of damage to existing connections, as is the case where cables are laid directly in the ground.
The author has not mentioned the v.r.i. or plastic-insulated cable in conduit system used for the many electrical connections between d.c. machines, exciters and control gear associated with the mill drives. This conduit system involved running a considerable number of screwed galvanized pipe connections, some of which were 3 in. in diameter, between each item of equipment. All this pipework had to be cut, screwed and laid after shuttering but before casting the floor, which involved very careful planning during the construction stage.

The first cost of this system must have been high compared with ordinary lead-covered multicore cables, either cleated under the floor or run in ducts and, furthermore, the conduit system cannot cater easily for modifications or extensions to the plant.

It would be interesting to know the result of the first two years’ service at Vanderbijl and also whether any condensation of water occurs in this conduit which I believe is not drained. Faults within conduit are perhaps unlikely but if they do occur in the system used surely such faults will be difficult to locate and even more difficult to repair. Workmen have been known to strain cable insulation when pulling wires through conduit and such damage frequently reveals itself only after a period of time.

With regard to the use of rotating amplifiers, there are certainly many rows of these little sets at the works and sometimes I wonder whether some manufacturers are not going a little too far in this respect, namely, by putting in more machines and contactors than are really necessary. As the author explains, these machines magnify a signal sometimes one thousand times or more and can be invaluable due to their very fast response. I often feel that more thought should be given to the judicious use of dry-plate rectifiers for blocking d.c. circuits as well as non-inductive resistances for altering the time constants of field systems, etc., in order to reduce the number of rotating amplifiers and to simplify fundamental control circuits.

Where extremely fine speed matching is necessary it would be interesting to know whether field circuits, associated with the amplifiers described by the author, have any inherent compensation for variations in temperature, as I note that the tuning circuits alter slightly for summer and winter conditions, and such variations would, no doubt, also be experienced after starting up the plant from cold.

K. D. STARR (Associate Member): The paper has, I am sure, given a very good general idea of the layout and capacity of the electrical plant installed at Iscor Vanderbijl Park, and my only regret now is that time did not permit Mr Hoogenhout to go into more detail on the various individual items. Perhaps, however, I might be permitted to ask for a little more information on certain points.

With regard to the hot-strip-mill flying shear, I note that the length of strip cut is controlled by varying the speed of the shear drive with respect to the speed of the last mill stand, from which I assume that the shear drums run continuously. In a later paragraph, however, it is indicated that a high acceleration and deceleration of the drive motor are essential for successful operation of the shear which appears to contradict this assumption.

The method of threading a new coil through the cold-strip mill is noted, but would it not be possible to save time by butt-welding the beginning of the new coil to the end of the old one, and then shearing after the passage of the weld through the mill? Alternatively, stitching could be used as is the practice in some British steel mills.

I was very interested in the type of motor-house air filter in use, but could Mr Hoogenhout tell us what type of adhesive oil is used on the collector plates and why it is necessary to allow this to dry for about an hour after spraying?

One of the most interesting sections of the paper in my opinion is that devoted to a description of the rotating amplifiers in use on various sections of the plant. Mr Hoogenhout mentions the rototrol, amplitrode and magnavolt exciter, but makes no mention of the cascade-exciter system of control as used by the company with which I am associated, and I would like to give a brief description of this system. Applications of this type of control are innumerable but as being the greatest probable interest the example I have selected is the cascade-exciter control of a slab-shear motor.
Fig. A shows a simplified schematic diagram of the system, and it will be noted that the motor armature and the generator armature are connected solidly together in series. Excitation for the motor is provided by a constant-voltage exciter, but excitation for the generator is derived from the cascade-exciters set consisting of the two small machines M.E. and P.E. These two machines are mounted on a common bedplate and driven at constant speed by a suitable motor. The generator field is excited by the main exciter (M.E.) which in its turn is excited from the pilot exciter (P.E.) which has two control field windings and two stabilising field windings. Winding A is arranged to receive a voltage which is the difference between a pattern voltage selected by the master controller (not shown in the diagram) and the generator voltage. At steady speed these two voltages nearly cancel, the small difference being sufficient to produce the generator excitation necessary to maintain this speed. Winding B is arranged to give a current-limiting feature and comes into action to oppose or assist winding A when rapid changes in the pattern voltage brought about by movement of the master controller would otherwise cause excessive currents in the main-loop circuit.

This current-limiting feature works in the following manner.

Field B is connected in series with a shunt in the main-loop circuit, and the current-limiting rectifiers. If the current in the main loop exceeds the safe value then the rectifiers permit current to flow through winding B, the sense of which is such that it opposes winding A, thereby reducing the voltage of the pilot exciter, and hence the main exciter and generator. Thus a rapid movement of the master controller from 'stop' to 'full speed' will first rapidly raise the generator excitation by the effect of pilot-exciters field A until the current in the main loop reaches the limit set by the shunt after which any further increase in the pilot-exciters voltage will be checked by field B until the increase in speed of the main motor causes a fall in current. This process will continue, keeping the current sensibly constant until the main motor is up to full speed. The rate of fall of the pilot-exciters voltage is similarly controlled by the main current during retardation.

The control of the motor using this system is very simple and smooth. If the control lever is pulled hard over from 'stop' to 'full speed', the following sequence takes place.

The reference potentiometer which provides the pattern voltage for field A of the pilot exciter is energized. A contact on the master controller applies full pattern voltage to field A via the reference potentiometer, and the pilot-exciters voltage rises rapidly exciting in turn the main exciter and the generator field. The generator voltage also rises rapidly and a heavy current builds up in the main loop. The voltage drop across the shunt increases and a current will pass through the pilot-exciters field B thus keeping the loop current closely to the limit set by the shunt. The motor will accelerate rapidly under current control until it reaches full speed when the loop current will fade and the current in field B will fall to zero. The current in field A will be governed by the difference between the selected pattern voltage and the main-generator voltage and will be sufficient to maintain full speed.

If the controller is now moved to 'stop', the pilot-exciters field A is short-circuited by a contact on the master controller thereby causing a rapid fall in cascade-exciters and generator voltage and the motor will regenerate into the loop. The current flowing in field B is now reversed and again serves to keep the loop current to a safe value.
Discussion on
A 66-kV grid in Northern Rhodesia

By T. K. A. DOUGLAS, B.Sc. (Associate Member)

Transactions, February 1952

R. R. GILMOUR (Associate Member) (contributed): I was surprised to learn of a grid system and, moreover, one operating at as high a voltage as 66 kV, in Northern Rhodesia. Mr Douglas has, therefore, revealed not only electrical progress in this territory but also, consequently, apparent major general development.

The questions I have to ask the author will be confined to e.h.v. transmission and the interconnection of power stations.

Transmission lines

Most of the important points in this connection have been touched on and will satisfy most power engineers. There are, however, other points which may possibly not concern the author directly, but are of certain importance as far as I am concerned and I shall be glad to have his comments on these which are chiefly concerned with interference with electrical communications, etc.

(a) Asymmetrical potentials

As far back as 1919, the Railroad Commission of the State of California\(^1\) reported on inductive interference from transmission lines and from this report it appears that the configuration of the conductors has a bearing on the matter. This is due to a residual e.m.f., i.e. taking the three conductors as a whole and comparing with earth potential. This e.m.f. is termed the 'asymmetrical' voltage. The method of earthing the star points of a.c. generators and transformers also affects this e.m.f.

I shall be glad if the author could comment on this phenomenon and state whether he has had any experience with it from a point of view of interference with radio and telephone circuits.

According to the above commission it appears that triangular configuration gives the lowest asymmetrical e.m.f.

(b) Intensity of interference

Other observers (see Discussion, page 390, ref. 2) have confirmed that discharges from the line insulators are not only common, but are a normal source of interference from e.h.v. lines, but that regardless of the line voltage, the interference with broadcast signals is negligible 50 yards away from the line. Further, interference from these discharges can be quite severe even if there is no visible sign of sparking or corona.

I have found that the interference is more severe on the medium or broadcast bands than on short wave (i.e. say below 80 metres). Although I reside practically underneath a 33-kV overhead line, the interference is only really bad when a damp south-easter is blowing from the sea one mile away. I have improved the position by running my radio aerial at right angles to the above line.

However, I have investigated a case where the interference was very severe although the distance between the radio set and an 11-kV overhead line was 100 yards. In this case, however, the consumer was fed from a transformer mounted on the last pole of this line and, moreover, the l.v. line was carried by the h.v. line poles; in addition the radio aerial was running parallel with the l.v. service connection, from the l.v. feeder which extends 100 yards beyond the termination of the 11-kV line.

(c) Effect of types of insulators

The types of insulators used also have a bearing on the intensity of the interference. A low-capacity type of insulator is desirable
in this connection. Langton and Bradshaw investigated this aspect very carefully with respect to atmospheric conditions, etc.

As my experiences in these matters have been concerned with h.v. lines only in the Cape Peninsula and near the sea, it would be interesting to learn of experiences with similar lines in Northern Rhodesia with its very different climatic and atmospheric conditions.

(d) Earthing

I note that the star point of the 66-kV winding of each transformer is solidly earthed. I would like to know
(a) whether spikes or plates are used,
(b) the depth of earth into which these are driven (or buried),
(c) the method of bonding the earth wire to the earth electrode,
(d) whether any additional precautions are taken in order to reduce electrode resistance.

The author states that pole footing resistances of 2,000 ohms have been encountered. Can some details of the method of measurement of this resistance be given?

As regards the target for 10-ohms footing resistance is this the value with or without the overhead earth (or 'ground') wire connected?

Has the author ever measured any significant potentials between any e.h.v. pole and points in the surrounding ground?

Protection and communication

The use of carrier currents is interesting and the author's reasons for selecting this form of protection for his relatively long h.v. transmission lines is clearly understood. Apart from the high-speed clearing characteristic, can the author say whether this type of protection is as reliable as the usual or older types?

The power supply for the thermionic equipment is provided by m.g. sets which are battery driven. Do the machines not cause interference, or are steps taken to prevent this? Would it not be preferable to use a battery only for the purpose?

The use of single side-band transmission for telephony is understood, but I would like to know whether the author has ever tried or considered frequency modulation for this purpose.

I note that the important point of likely interference due to single-phase use with earth return has been mentioned. Has the author had actual experience in this connection, and has he ever considered the theories of Pollaczek, Carson and others relating to mutual inductance between adjacent lines, with earth return?

Metering

I note that the demand is integrated over half an hour. Since a printometer, operating off induction watthourmeters is used for this purpose, I presume that the exponential thermal characteristic is not the direct basis of the time interval. If this was so, I take it that a time interval of 15 minutes would rather have been chosen for this type of instrument. However, half an hour is not an unusual period for demands concerned with interconnected power stations, whether linear or exponential response-type instruments are employed.

The use of the summation transformer is interesting. Does the author have much trouble with the ratchets on the import and export meters? I was responsible once for having ratchets made for meters for a similar purpose. The most important part of the work was the obvious difficulty of obtaining a suitable compromise between satisfactory operation of the ratchet pawl and serious impairment of the meter accuracy, or shape of the characteristic error curve at low loads. Satisfactory results were eventually obtained and have given good service for years now.

Has the author ever considered the use of a multi-element summation watthourmeter, operating a simplex maximum demand indicator, in preference to the multi-element mechanical instrument which he has in use? Does this instrument require much maintenance? Is there a difference between the mine load summator and, say, the Mufuira generator summator?

I take it that as the meter current coils are now operating from 66-kV current transformers at Roan Antelope, the potential coils are supplied via 66-kV potential step-down transformers.

In closing, I would like to ask the author whether,
(a) disputes ever arise over meter readings or consumption?
(b) the meters are tested as a matter of routine?
(c) a meter-testing station is in existence for meters associated with the grid? If so, particulars would be welcome.

Reviewing the meter arrangements, which are complicated due to obvious reasons, I consider that the author is really to be complimented inter alia on the meter engineering side of the system.

I hope I have not drifted too far from the trend of Mr Douglas’ paper, but if he can offer any answers or comments on my queries I can assure him these will be appreciated.

REFERENCES

1. Inductive interference between electric power and communication circuits. Railroad Commission of the State of California (1919).

Book Review


This booklet is invaluable to all engineers faced with the selection of circuit-breakers rated and tested in accordance with British and American standards.

It sets out in a concise manner the methods adopted in the two countries for assessing the rating and performance of their respective circuit-breakers and draws attention to the fundamental differences in the ratings when based on the symmetrical and asymmetrical currents. Worked examples are given to illustrate the points made.

Appendices set out in tabular form the relative performances at various operating times of the British and American breakers for any predetermined fault capacity, and the standard voltages, frequency and short-circuit ratings and other factors used by the two countries.

S.H.A.