rotary converters dropping out of step, but I have known cases where motor-generators have kept in step even with a variation of 20 per cent, in the speed of the generating plant.

Mr. Stewart. Mr. ANDREW STEWART *(communicated)* : The first point which caught my eye as I read Mr. Riseley's paper was the amount of plant in the Kander Power-house, some 3,720 k.w. on an area of 4,080 square feet, or ri square foot per kilowatt. This is a figure which, although it has been improved by some of the high-pressure water-power plants employing Pelton wheels on the Pacific coast, is nevertheless a good example of a Continental water-power plant with a medium fall. Having beside me a few figures for power-houses in New York and Berlin, I give them below, with the relative position of the boilers and the type of engines, all of which influence the area required per kilowatt.

Name.	Total K.W.	[illegible] of [illegible] Feet	Square Feet per K.W.	Arrangement of Boiler.	Type of Engines.	Size of Unit.	Revs. per Minute
Metropolitan, [illegible].Y.	38,500	48,800	1·26	[illegible] 3 floors	Vertical [illegible]	4,500 h.p.	75
Kin[redacted]idge, [illegible].Y.	78,830	56,000	1·4	On 2 floors	[illegible]	4,500 ,,	75
[illegible]hattan, N.Y....	82,416	40,000	2·05	O[illegible] 2 floors	[illegible] plex [illegible]	8,000 ,,	75
Oberspree, Berlin	43,000	28[illegible]000	6·5	On 1 floor	Horiz[illegible] triple Gorlitz	1,000 ,, 2,000 ,, 3,500 ,,	83
Moabit, [illegible]rlin ...	33,000	363,000	11·0	O[illegible] 1 floor	Horizontal triple Sulzer	3,500 ,,	83

Mr. Stewart.

Oberspee and Moabit will have all extension units of 6,000 H.P., and figures given are based on ultimate capacity of station when buildings are full.

The German H.P. is 1½ per cent. smaller than the English, but that does not materially alter the figures. On my visit to the Berlin stations some months ago neither had reached its full capacity, but there was no evidence in either case of economical tendencies as to ground space, chiefly because ground was very cheap, each station being located some miles from the centre of the city. The figures probably represent the extremes of large power-station design, as even in London the area per kilowatt of any of the stations is not much less than that of the Metropolitan Station, New York, although in conversation with the engineer of one of the new underground railways for London I learned that with Parsons turbine units it was hoped to get the ground space in one power-station down to one square foot for each kilowatt installed.

Mr. Riseley's reference to the transformation of three-phase currents by three single-phase transformers is also interesting, instead of the more usual Continental plan of employing three-core transformers for this purpose. The ease with which another single-phase transformer may be switched in to replace any one of the three should it happen to break down, is not sufficient to justify the extra capital expenditure, which may be 10 to 20 per cent., depending upon the size. In addition to this, I note that a good proportion of the power at Berne is used as single-phase, where of course there will be some tendency towards unbalancing. This tendency can best be checked, if not quite suppressed, by the use of three-core transformers, the interaction of the three phases being sufficient for this purpose. If Mr. Riseley has heard this point raised at Berne, perhaps he can throw some light on it.

Another interesting point is the Lecco-Colico line, where it appears that 15-cycle 3-phase currents are employed throughout. It would be interesting to know what considerations led to the choice of this low periodicity; certainly the motors and transforming apparatus would cost a good deal more than with a higher periodicity. One consideration which appears to justify this low periodicity would be the greater apparent resistance of the rails with currents of a higher periodicity. If the rails have a large section, this would probably become a matter of considerable importance, but it is doubtful if it was the reason for the adoption of a periodicity of 15 cycles. Perhaps it may have been due to mounting the motors direct on the axles, and using driving-wheels of small diameter; this, with a small number of stator poles, say four, would correspond to the higher speed mentioned by Mr. Riseley, viz., 60 kilometres per hour, but this would involve wheels approximately 30 inches diameter, and it is improbable that the motors could be mounted directly on the axle in the space available. There must of course be some good reason for such a departure from recognised practice. Another point is the statement that each bogie on the cars has two motors, one primary and one secondary; this would lead one to suppose that they are arranged permanently in cascade, which seems unlikely, unless when running at 30 kilometres per hour, while the next paragraph says "all motors are primary." It is difficult to reconcile

Mr. Stewart. these two statements, as they indicate directly opposite practice, and I should like to have Mr. Riseley's views.

Mr. Woodhouse. Mr. W. B. WOODHOUSE was interested in comparing the methods adopted for the protection of the system in the stations described with those used in other countries. He noted that the use of fuses was general, but he was surprised to find aluminium fuses still in use. Aluminium had been used because its specific heat was large, and it was possible, by carefully proportioning the cooling surface, to make such a fuse act as a time-limit cut-out, but the difficulty of making a good connection had caused most engineers to abandon its use in favour of tin, to which copper connecting strips were sweated. Modern practice in this country and in America was to abandon fuses altogether in favour of automatic oil-break switches; feeders were protected by overload time-limit switches at the generating end, and overload and non-return power switches at the receiving end. He did not consider automatic switches or fuses necessary on generators, an oil-break switch being sufficient, if properly enclosed in an iron box; he quoted a case of such a switch repeatedly breaking 12,000 kw. at 45,000 volts without damage. With regard to a suggestion of Mr. Riseley's, that small engines should be used which would pull up on a short-circuit, the speaker could not agree with this rather primitive method, as all the synchronous sub-station machinery would undoubtedly fall out of step. An automatic switch was the proper thing to use.

Mr. Stoney. Mr. G. G. STONEY said he was much indebted to Mr. Riseley for his paper. It enabled us to compare our systems with those of our Continental competitors.

When he was over in Germany the thing which struck him most was that the capital expenditure was excessive, especially for buildings. Take two modern stations. The style of buildings would never be countenanced in this country, and the space occupied by the plant was excessive. It was 1½ square feet per kilowatt, without taking into account switch-room. If the switch-room were taken into consideration it would work out at 1¾ square feet. The space used was 1⅛ at Neptune Bank. In one station £130 per year was spent on washing floors. The result of this excessive expenditure would be disastrous at some future time. The charge for current was higher than it was in England, being as high as 7d. and 8d., whilst in Newcastle it was 4½d.

His opinion was that for real sound work England was far ahead of the Continent. He quite agreed with Mr. Woodhouse that fuses were a great nuisance. He would be inclined to do away with fuses, especially main fuses, on machines. Fuses of aluminium in china handles, of the Brown-Boveri type, seemed to work fairly well.

Mr. Vesey Brown. Mr. C. S. VESEY BROWN said that one envied the French, Swiss, and Italians in the possession of their magnificent waterfalls, and unfortunately the conditions in England were so different that manufacturers and others connected with central stations were obliged to use steam to compete with their Continental neighbours. He did not know of any other water-power station than that of Reinfelden, in Germany, where most of the stations were steam-driven.

In reference to the author's remarks on fuses, he had found that the general rule on the Continent was to use pure silver, which was far more reliable and certain to go at the proper current density. For his part he had given up the use of fuses for large currents except where it was required to disconnect any leads, and preferred to use instead a good maximum automatic cut-out with a carbon break attached. Mr. Vesey Brown.

At his first visit to the Cologne Station in 1891 he found that the authorities were most particular as regards periodicity and pressure, and, in fact, were so successful as to be able to run about two dozen clocks in synchronism with the generating plant, and these clocks were set once a week.

There were many opinions as to the question of using storage batteries, and they had certainly stood the test of time at Dresden and Dusseldorf, but the tendency being all in favour of three-phase generation had to a certain extent displaced the storage battery. There was certainly the point as to constancy of pressure which was more particularly brought to the front when Nernst lamps were used on the circuits, and in his opinion the use of the Nernst lamp required that the pressure should not vary beyond the very narrowest limits from the standard pressure. It seemed a pity that in the town in which they were at the present moment, that the use of the Nernst lamp had to a very great extent been killed by the great variations in pressure to which the distributing system was subjected, and he thought that this might be remedied by the use of storage batteries.

On the Continent the price of supply was as a rule higher than in this country, but this was due to the very lavish manner in which the buildings had been laid out, and as the upkeep was heavy, so the consumer had to pay more for his supply. The Continental proprietors were satisfied with a slightly smaller return on the capital put into the stations, for as a rule, where the stations were not owned by the local authority, they were owned by manufacturing companies, who put a good price on the value of their plant at the commencement. In some cases the tax to be paid by the concessionaire to the local authority before the shareholders received anything was 6 per cent. on the capital employed; in others it was as high as 1d. per unit.

Referring again to the use of storage batteries to steady the pressure, he was informed at Essen that the town authorities imposed a fine for irregularity of pressure and failure to supply, but that up to the present no fines had been imposed in consequence of any failures, etc.

In his opinion the German stations were much better finished than the French and were generally cleaner, though they were both a great deal ahead of this country in this respect.

Mr. C. TURNBULL said he was interested in Mr. Riseley's remarks on cellular switchboards. People were often led to believe that the only fault of this type of board was its high cost, although the board certainly appeared rather inaccessible. He was pleased to hear the criticism of one who had used them. Mr. Turnbull.

With regard to running dynamos without fuses, it was to be observed that an engine's power went off rapidly as soon as it slowed down, and he believed it well worth while—speaking from experience—to have

Mr. Turnbull. dynamos large enough to pull the engine up without damage to the dynamo.

Mr. Snell. Mr. J. F. C. SNELL said he would like Mr. Riseley to tell them whether he found the oil-break switch more in use than the air-break switch. He understood that the Continental practice was to use the horn-switch. He was, however, sufficiently English to have adopted oil switches in connection with his three-phase plant.

It occurred to him that the money spent on buildings—particularly on the engine rooms—on the Continent was very excessive indeed, owing to the fact that they used slow-speed engines which covered a great deal of room. This was, of course, done with an object, the cost of coal being so great that they were obliged to adopt every possible means in their power to reduce the consumption per unit sold. The sub-stations of Berlin struck him particularly as being lavish. The walls in some cases were 36 inches in thickness, and the floors were most heavily made with glazed brick facings. Although land was dear, the fact of putting accumulators on the first floor when they could have been put in the basement seemed waste of money. While he thought that their engine rooms looked better, their boiler-house equipment was wanting when compared with English practice. English central station engineers would be ashamed of the usual Continental boiler house. The arrangement of piping also seemed to be bad. Supposing they had a superheat of 250° at the boilers a good deal must be wasted before reaching the engines, owing to the long pipes employed.

It was interesting to hear the remarks about the single-phase transformers. He found three-core much cheaper than three single-phase to install. None of the previous speakers touched on the question of railways. The Institution had wisely arranged a trip to Italy this year. He hoped the experiments on railway equipment being made in Italy would teach us a great deal and have the effect of awakening our English engineers.

Mr. Clothier Mr. H. W. CLOTHIER said he was not so favourably impressed with the design of Continental switchboards as Mr. Riseley. When he visited stations containing such switchboards he found that the backs were not open for inspection to visitors, and he instanced one place where he learnt that two men had been electrocuted behind the board. He alluded to the comments on British switch-gears, and thought that an unfair comparison had been made. The cellular switch-gears at present in use in this country were designed for pressures of about 5,000 volts and under, whereas the Continental system taken as an ideal was working at 13,500 volts; when the demand for higher pressures arose in this country we should produce designs to excel those seen hitherto by the author. He did not attribute so much importance to the duplication of 'bus-bars which introduced complication and chances of error. He drew attention to an error in one of the diagrams which was a good example of the difficulties due to too much complication; if the draughtsman could so easily err, what was to be expected of the operator?

Mr. Riseley had said that on the boards to be seen on the Continent, such as that at Paderno, there was "always another way round, *everything* being in *duplicate*, but he (Mr. Clothier) thought that an examination of the diagrams would show that such was not exactly the case. The 'bus-bars were in duplicate, but that was all. He maintained that apart from the complications involved (which were common to any type) there was no difficulty in obtaining by this means "another way round" on the British cellular gear; as a matter of fact he could mention many cases in this country where duplicate and even triplicate 'bus-bars were in use. Mr. Clothier.

He said that flare switches for alternating-current systems were fast dying out, because of the high voltage oscillation set up by the arc. In the light of our experience and the expert opinions of this country and in America, no one would think of installing switches of the same type as those in use on the Valtellina line.

He was entirely in accord with the author in his practical opinion as to dispensing with fuses on the generator circuits, fuses there were more often than not a nuisance; they were wanted on the feeders, and he thought reverse current indicators on each machine circuit were used to advantage.

Speaking of the general design of British switch-gears, he admitted that there was ostensibly much to be done before they could be considered perfect for extra high voltages; but in arriving at finality in design, if that were possible, we should take into account the enviable record of no fatal accidents on the Ferranti cellular switch-gear during all the years it had been extensively used on high-tension supply systems.

Mr. J. H. HOLMES said he had the pleasure of visiting Kander Power Station with some members of the Institution. Mr. Holmes.

The thing that struck him most was the great difficulty they had in regulating and governing their turbines. It seemed impossible to design an automatic governor which would be of any use. When he was there he had noticed the man at the hand-wheel, and he was interested to learn that he was still at it.

Mr. H. L. RISELEY, in reply, said that Mr. Stewart's figures of area of ground per kilowatt installed were very interesting, and he was sorry he could not add to the list. The sole idea of using single-phase transformers was, he was informed, for the convenience of changing over in case a transformer got damaged. *Valtellina Line.*—He presumed that the reason of choosing a periodicity of 15 cycles per second was the wish to mount the motors direct on the axles. The wheels, instead of being 30 inches, were 3·84 feet in diameter on the motor cars, whereas on the locos. they were 55 inches in diameter. The motors were mounted directly on the axles in a very interesting manner. The gear consisted of a very neat parallel-link connection between the driving hollow rotor shaft and the wheels. Each pair of wheels was keyed to the shaft, of which the diameter was 4½ inches less than the inside bore of the hollow shaft, and the link gear compelled the two to rotate accurately together while giving complete freedom to the wheel-shaft to rise and fall with the axle boxes between the horn plates without any vertical motion of the rotor, stator or motor as a whole. Mr. Riseley.

Mr. Riseley The whole weight of the motor was borne on springs; the bearings of the rotor shaft were fixed in the casing of the stator. The wheel was driven by pure torque, that is to say, by two equal and opposite forces producing no reactive resultant pressure in the bearings in which the rotor ran. The whole load, including the weight of the motor, was carried at the axle box.

As regards the primary and secondary motors, each motor car was fitted with two primary and two secondary motors, but on the locos. all four motors were primary, and speed regulation was obtained by using either one, two, or three, or all motors, to suit conditions. On the bogie cars each truck carried two motors, one on each axle. These were used in cascade up to half-speed, and also in slowing down from full-speed to half-speed. In accelerating from half- to full-speed, and in running at full-speed, one of each of the pair of motors was cut out and was running idle. Of course, in cascade-working during the first period of acceleration, the resistance was placed in the rotor circuit of the secondary motor, in the stator of which the voltage did not rise above 300, this being derived from the rotor of the primary motor, which current was drawn off slip-rings. The Controller had only three positions: (1) half-speed; (2) mid position, when the resistance was cut out and the primary rotor circuit was open, and (3) full-speed, for acceleration from half-speed to full-speed.

Mr. Woodhouse mentioned aluminium fuses and seemed to have the idea of making fuse contacts of aluminium strip. Messrs. Parsons & Co. used special blocks for soldering aluminium strip.

As regards the time-limit circuit-breaker he did not see any in operation, though he understood that they were experimenting in Newcastle with them and that they were working fairly satisfactorily.

Regarding the last paragraph of the paper his idea was, supposing you get a number of 100 k.w. generators running in parallel with identical engines of the same rated power. In that case, should any overload occur, all the engines would slow down together, instead of a more powerful engine trying to take all the load and thus upsetting the parallel running of the station. He only offered this as a suggestion.

In reference to Mr. Stoney's remarks, no doubt some of the Continental stations were got up most expensively, especially that of the Schuckert Corporation Station at Vienna. The work of cleaning the station was a big item; in some cases it cost £2 per week to keep the floor clean. He did not remember seeing a station in England kept so clean as the Continental stations.

In regard to the point raised by Mr. Vesey Brown about the cheapness of water-power abroad, the capital expenditure incurred in applying water-power was enormous. In some cases they were using steam plant, as the capital outlay in utilising the water was almost prohibitive, and they found it better to have steam engines.

With reference to sub-stations being well equipped, he did not know that it did not pay to put in all the automatic devices you can. It certainly saved labour.

Turning to Mr. Clothier's remarks: he did not think there was anything in the paper about Ferranti switchboards. There was more than

Mr. Riseley

one type of switchboard called multicellular. There certainly were several points on the Ferranti switchboard which could be improved. Accidents with it were not unknown. It certainly was an advantage to be able to get behind the board, which it was impossible to do with the Ferranti board. He agreed with Mr. Holmes that the governing at Kander was extremely bad. With a large volume of water rushing down under a high pressure, it was evident that the governing could not be very uniform.