THE FIRST TRANSMISSION OF ENERGY IN EUROPE BY MEANS OF TRIPHASE CURRENTS.*

By EMILE GUARINI.

THE transmission of electric energy from Hochfelden and Glattfelden to Oerlikon (a distance of about eleven miles) possesses the rare peculiarity of being up to the present the sole installation in Europe in which a triphase current is transmitted at 30,000 volts.

The Oerlikon works made this installation for the purpose of collecting accurate data for other installations, rather than for a really industrial purpose. It possesses, moreover, another factor of interest, and that is of being a sort of adaptation of an old installation of 15,000 volts. With a view to economy, the old material has been utilized to as great an extent as possible. But, for certain machines, the result has been a lower efficiency than that attained in the Oerlikon plant. Per contra, it has furnished many interesting data and been the cause of the devising of several peculiar arrangements.

The mean total energy furnished by the two hydroelectric plants at Hochfelden and at Glattfelden is 550 kilowatts. The two establishments work in parallel. That at Glattfelden is about one and a quarter miles distant from that at Hochfelden, and furnishes 120 K. V. A. under a tension of 5,000 volts. This energy is transmitted to the Hochfelden plant, where the tension of the current is raised to 30,000 volts; and the balance of the total output at 30,000 volts is furnished by the generators of this plant operating in parallel with those at Hochfelden. The excitation of the generators at Glattfelden is regulated from Hochfelden.

This latter plant includes three turbines and three generators of the "Lauffen" type, furnishing 100 volts and 1,200 amperes at a speed of 187 R. P. M. and 50 periods. Each generator is direct-connected to a triphase transformer of a construction exactly like those that were shown at the Frankfort Exposition in 1892, for the transmission of power from Lauffen to Frankfort. At Oerlikon, the current at 30,000 volts is reduced to 230. The secondary terminals of the transformers of the secondary station are connected to bus bars in parallel with a 600-kilowatt generator direct-connected to a Sulzer steam engine, the normal speed of which is 94 revolutions a minute.

the surface of the ground. There are but three service wires. The resistance of one of the wires is 31 ohms. At about 1.5 meter (4.6 feet) beneath the wires for the high-tension current is the outgoing and the incoming wire for the telephone. These wires are carried by the same poles as the others. This telephone line connects the primary and secondary stations. The wires are crossed twenty times, for the entire distance. Telephone communications can be kept up during the service. If a defect in insulation occurs in the high tension circuit, the telephone bell immediately begins to operate on account of the dissymmetry of the distribution of electricity. This bell therefore always signals defects in the insulation. At each end, as well as at the center of the line, there are about three lightning arresters of the Siemens type, having a 2-inch air gap. These operate during every storm in the vicinity of the line without the least disturbance making itself felt in the service. Moreover, for several years past there has been no serious derangement of any account in the service due to lightning.

The 800 insulators that carry the wires are of different types. There are also among others, about one hundred large delta bell insulators of 25 centimeters (9.8 inch) diameter, about 300 white porcelain insulators such as were employed on the Lauffen-Frankfort line, about 200 brown insulators of practically the same size, and 200 smaller insulators in the form of a plate.

By means of the Oerlikon high-tension interrupters shown it is possible to interrupt the entire current of the secondary station without any visible spark. The interrupter consists of a lever and toothed sector, and the interruption is effected in porcelain tubes. With one of these interrupters it is possible to break a circuit with a charge of 3,500 horse power represented by a triphase current having a tension of 3,800 volts; and this is certainly an evidence of its excellent construction. The transformer room at the Oerlikon station has four transformers of a recent type—the same as that which before very long will be employed at the primary station as a substitute for the old transformers, which have a low efficiency.

The capacity of each transformer is 150 kilowatts. The high-tension windings as well as the low-tension ones are connected triangularly. The transformers

speed of the turbines and a constant excitation of the generator, the voltage at the low-tension terminals at the secondary station was when running with no load, double the voltage at full load, as long as the transformers of the two stations were in service. With the new transformers, the variation in voltage will be about 30 per cent less. Between full load and no load the difference in voltage of the generator driven by the steam engines, is 40 per cent. Under such conditions, the working of the two plants in parallel is obtained without any difficulty. The regulation of the voltage is extremely simple. In the primary station neither the excitation of the generator nor the number of revolutions of the turbine is regulated, and it suffices to regulate the current derived from the exciter actuated from the main transmission shaft at the secondary station. This is done automatically by means of a Thury regulator, which gives extremely satisfactory results. The voltage, regulated automatically by the variation of the shunt current of the exciter, does not vary more than ± 2 per cent in ten seconds. As the asynchronous motors were for the most part installed five or ten years ago, their factor of power is relatively low and does not exceed 0.5 at full load. The factor of total power of the distributing system is carried to 0.8 by means of three large synchronous motors of a total capacity of 40 kilowatts. Upon superexciting these they become capable of furnishing an important component of current, which is in advance of the current of the system. The manufacturers are of the opinion that the voltage regulator can be adapted to each exciter or to each generator, and that its operation is influenced neither by the variations in speed, lag in the phase, nor by change of load. There is every reason to believe that this system of regulation will before long replace all the systems of compounding of the alternators that require complicated connections of the exciter or commutations, and that cannot act directly upon the voltage at the terminals, but must regulate certain magnetic fields in more or less direct relation with the main current. The automatic regulator is a sort of relay for the voltage, and can be over- or under-compounded at will. For this purpose the windings necessary for the compounding are provided for in the regulator.

The elevation of the tension from 15,000 to 30,000 volts necessitated the replacing of a certain number of insulators that had proved inadequate during damp

TESTING STATION OF THE HOCHFELD-GLATTFELD-OERLIKON LINE.

A THIRTY-THOUSAND-VOLT POWER TRANSMISSION LINE.

TRANSFORMER WITH ARTIFICIAL VENTILATION.

The current is utilized at Oerlikon to operate 200 synchronous motors, 60 of which are used for actuating the traveling cranes.

During the normal service two generators and one transformer are in operation at Hochfelden. The high tension windings of one of the transformers are closed and each phase of the high tension windings of the second transformer is connected separately in series with the coils of the first transformer.

The windings are contained in a cast-iron box filled with oil, which is set in circulation by a pump, and, from the box, passes through a coil of pipe surrounded by cold water. The transformer that transforms the current coming from the works of Glattfelden is cooled by air.

The use of transformers at the primary stations presents several advantages over the direct production of high tensions by alternators. Although the line follows a river and is much exposed to strokes of lightning, none of the parts of the transformers has ever been damaged during a thunder storm. This fact indisputably proves the security of service given a high-tension line by a transformer connected between the generator and the line. Besides, owing to the fact that transformers permit of reaching a tension much higher than that which can be practically produced directly at the terminals of the generators, it will be possible to effect in the transmission line a saving of copper that will compensate for the increase in expenses occasioned by the cost of the transformers. Finally, the liberty in the choice of tension at the terminals of the generator will permit of reducing the cost of the latter, by employing bar windings, for example. At the generators and at the transformers the middle conductor is connected with the water main. At the primary station there is placed in the open air between the line and the transformers fusible bars about three feet in length.

The line itself comprises four conductors 4 millimeters (.157 inch) in diameter. These are spaced 50 centimeters (20 inches) apart, are carried by 260 poles, and are from 8 to 10 meters (26¼ to 32.8 feet) above

are provided with an oil bath, and the oil is cooled by water that circulates in a spiral pipe arranged in the oil receptacle. If, under a charge of 10 kilowatts, the circulation of water be dispensed with, the temperature of the oil will rise to 35 deg. C. (95 deg. F.). Before long, the transformers of the primary station will be replaced by a modern transformer of 450 kilowatts capacity, with artificial refrigeration by air. The new transformers, one of which is shown, are coils so constructed as to be capable of supporting a service tension of 50,000 volts, in order that experiments also may be made with this very high tension. The difference between the old and the new transformers is very characteristic of the progress made in recent years in the domain of such apparatus. The following are the characteristics of the new type of these apparatus:

Power	150 K. V. A.
Weight, total	2,200 Kg. (4,850 pounds)
Weight of copper	200 Kg. (440 pounds)
Weight of iron plate	680 Kg. (1,500 pounds)
Weight of oil	650 Kg. (1,432 pounds)
Weight of oil receptacle...	560 Kg. (1,234 pounds)
Losses in iron	2,200 watts
Losses in copper	2,000 watts
Efficiency	97.2 per cent
Fall of maximum tension..	3 per cent

The 600 K. V. A. generator at the secondary station is of the flywheel type with stationary armature and circle of revolving poles. The movable part carries 64 polar cores with magnetizing coils. It has an efficiency of 95 per cent. From the movable part, which is in the form of a channeled pulley, a portion of the energy of the steam engine is transmitted over a main shaft from which it is possible to actuate two dynamos for the lighting. In the construction of the generator it became necessary to take account of the fact that it had to operate in parallel with the transformers, and, consequently, in order to assure a proper operation, to admit for the generator a relatively great fall in tension, seeing that the total difference of the tension of the transmission of energy is about 100 per cent between full load and no load. With a constant

weather. The transformers wound for a maximum tension of 50,000 volts were afterward installed. Nevertheless, before commencing a regular service with the tension of 30,000 volts, some experiments were made for the purpose of studying the effect of the charging currents upon the current and the tension of the installation, as well as the losses that might take place in the line.

Upon comparing the losses in watts in various experiments, it was found that those upon the line rapidly increased with the tension. They were 1 kilowatt at 20,000 volts tension, 4 kilowatts at 30,000 volts, and 10 kilowatts at 40,000 volts.

It has not as yet been possible to ascertain how much such losses can be diminished by employing larger insulators. Moreover, as we have already said, the tension has not been raised through motives of economy. In making this installation, the Oerlikon works proposed before all else to study thoroughly a high-tension arrangement, to collect practical data, and to find arrangements adapted for assuring an absolutely certain service at such a tension, in order to be able to undertake and guarantee the construction of a 30,000-volt installation. The object of the first experiments was to obtain a general idea of the conditions of operation that had to be expected; but other phenomena supervened to make the question more profound. It was found especially that there was a great dissymmetry between the three phases and that according to all appearances, the influence of the dissymmetry was so much the greater in proportion as the drop in voltage of the generators and transformers supplying the line was greater. The phenomena were identical with the large and small motors.

An endeavor was naturally made to remedy the dissymmetry of the line as simply as possible. In order to do this, the latter was divided into three equal sections, and in each of these the connections of the wires were reversed in a cyclic order. For practical reasons it was impossible to make the three sections exactly equal. The experiments were therefore performed over again after making special arrangements. A special switchboard (Fig. 7) permitted of connecting the main current coil of the voltmeter and am-

* Specially prepared for the SCIENTIFIC AMERICAN SUPPLEMENT.

meter, without interruption, one or the other phase. Moreover, it is possible to connect the shunt coil of the wattmeter, between the neutral point of the generator and the different phases, or, if it be desired to measure the watts according to the double wattmeter method, to connect the secondary coil of the wattmeter between two conductors. A special commutator permits of reversing the direction of the shunt current of the wattmeter.

The experiments were performed under very unfavorable atmospheric conditions.

The results obtained have permitted of drawing up the following table, in which are given the losses of energy that occurred in the different atmospheric conditions and at different tensions:

State of the Atmosphere.	Temperature of the air.	Losses in Kilowatts.			
		20,000 V.	25,000 V.	30,000 V.	34,000 V.
Cloudless sky and dry weather	+25°	0.6	0.7	0.9	1.0
Cloudless sky; hail during the night preceding the experiments	+5°	0.68	1.05	1.8	3.1
Fall of snow in very fine flakes, temperature below the freezing point	-4°	?	1.4	2.2	3.9
Sky cloudy, and rain a few hours previous to the experiments	+7°	1.3	2.0	3.0	4.2
Fall of snow in fine flakes, temperature above the freezing point	+15°	1.5	2.7	4.9	8.7

These experiments have shown a curious relation between the current of the line and the watts absorbed by the latter. The intensity of the current increases much more rapidly than the voltage. Such intensity, measured in the low-tension windings of the transformers, is proportional to the intensity of the high-tension current.

"It is noticeable that, without exception, these criticisms have been not by men practical in the manufacture of iron or steel, but by that class of scientific dilettante who assume with an array of figures and formula to prove with equal facility either side of a question that their sympathies happen to be enlisted upon."

"The truth of the blast furnace is that it is a highly economical device for accomplishing its end and will continue to be so until methods be found that will perform its functions for less money."

"Some classes of ore may now be more cheaply reduced to metal by other means than the blast furnace, making a product whose analysis cannot be produced in the blast furnace at all. Given a magnetic ore-carrying gangue, sulphur, and phosphorus in prohibitive quantity for making good steel economically, such ores find no market tributary to the blast furnace."

"On the other hand such ores may be crushed, magnetically concentrated, electrically smelted and produce the best of steel at a price which can compete with an ideally situated blast furnace."

"In last year's paper I made the assertion that 'the work of the electric furnace was performed upon a ton of ore with something less than 500 K.W.H. of energy.'"

"Upon this basis one of our learned members accorded me an efficiency of 83 per cent, which he followed up by saying was impossible. In truth, at that time I was doing 10 per cent better than that, or an efficiency according to his figures, of 91.3 per cent."

"To-day I am prepared to report to you that I am doing the same but better work, with one-half the K.W.H. reported to you last year, and it is with a spirit of some amusement that I contemplate what efficiency I am attaining to-day, assuming always, that upon the basis of 500 K.W.H. per ton I was entitled to an efficiency of 83 per cent. Three problems have presented themselves for solution, in the conduct of my work; first, the power required to agglomerate and sufficiently heat for subsequent reduction; second, the regulation of the size of the agglomerated particles,

that he was convinced from careful observation, that this was due to the reaction between FeS and FeO, at the high temperature of the electric furnace. Mr. Becker questioned the reaction, citing an experiment which he had made in which he attempted to make metallic iron by the reaction of iron sulphide and oxide, ending in failure. He also cited the unsuccessful attempts to obtain metallic nickel by the reaction of nickel oxide and sulphide."

Mr. Scholl asked as to the purity of the product of Ruthenburg's furnace and what became of the impurities. Mr. Ruthenburg explained that all impurities were primarily removed from the ore by magnetic concentration, so that practically pure iron oxide was what was supplied to the electric furnace. Therefore, the sole duties of the electric furnace were, first, to agglomerate the finely divided portions of ore into solid coherent particles that would not pack and impede the flow of CO. Second, to impart so many heat units to the ore that reduction through CO would be complete."

Mr. Ruthenburg also called attention to the fact that iron ore was unique in its property of being reduced by CO at a temperature not very much greater than that of boiling water, although at higher temperatures short of melting the reduction is more rapid."

In closing the discussion, Prof. Richards said that at last year's meeting, in figuring the efficiency of the Ruthenburg furnace, based upon the figures given at that time, he had assumed that the ore was melted and that the work of the furnace was intended to prepare ores for the blast furnace. In the new light of the present day, he congratulated Mr. Ruthenburg on the success of his achievements and thought there was great promise of electrically produced steel assuming an important place in the economic production of that metal in this country."

EMANATIONS OF RADIUM.—With reference to recent researches of Crookes on this subject (see The Electrician, vol. 1, p. 986), J. Elster and H. Geitel de-

TRANSFORMER OF THE SECONDARY STATION AT OERLIKON.

COMMUTATOR PANEL OF THE HOCHFELD-OERLIKON LINE.

HIGH-TENSION INTERRUPTER.

A THIRTY-THOUSAND-VOLT POWER TRANSMISSION LINE.

This short account, we think, will permit of an idea being obtained of the experiments performed during two years with 30,000 volts. The experiments that it is proposed to make with 50,000 volts will not fail to be interesting, and will permit of collecting a large number of data, both practical and theoretical, upon high-tension transmissions, which data will prove of utility not only for the Oerlikon works, but also for all those who are occupied with the electrotechnics of high tension, into which such experiments might be the means of introducing important modifications.

ADVANCES IN THE ELECTRO-METALLURGY OF IRON.

ONE of the most interesting papers read before the fourth general meeting of the American Electrochemical Society, held in Niagara Falls September 17, 18 and 19, was that of Mr. Marcus Ruthenburg on "The Advances in Electro-metallurgy of Iron Production." Mr. Ruthenburg has for years been experimenting in this important field, and has contributed much to what appears to be approaching success in the development of an economic process, so that what he says on the subject is of world-wide interest.

Mr. Ruthenburg's paper and the discussion that followed were as follows:

"At the last meeting of the Society a paper was read for me upon the 'Electro-metallurgy of Iron and Steel.' In the discussion which followed the reading of the paper, as well as in the technical press of this country and Europe, there has been a mild skepticism as to the possibility of competing with the blast furnace in the production of iron and the further reduction of this iron into steel by the Bessemer converter or the Siemens furnace."

and third, the amount of reduction of the agglomerated material."

"The status of those three problems to-day is that a ton of ore is being agglomerated with an expenditure of about 250 K.W.H."

"The size of the product is under perfect control."

"The reduction is being made absolute. Inasmuch as the only function of the electric current is to agglomerate the dusty particles into coherent masses without binder or flux, and to convey a sufficient quantity of heat to the ore in the soaking pit, to permit the reducing agents to perform their functions, it will be readily comprehended that the heat and current losses due to maintain a molten mass are lacking."

In the discussion that followed the reading of Mr. Ruthenburg's paper, C. J. Reed, of Philadelphia, asked as to the utilization and disposition of the calories consumed in his electric furnace and soaking or reducing pit. This phase of the question was answered for Mr. Ruthenburg by Alfred H. Cowles, who said he had made a study of the heat efficiency of Mr. Ruthenburg's work.

According to Mr. Cowles' figures, the heat units imparted to the agglomerated ore by the electric current in passing the ore through the rolls, is sufficient to supply the needs of the ore for its reduction by CO, which is supplied to the bottom or cooler end of the soaking or reducing pit. The CO is pre-heated by being passed through heated checker work surrounding the soaking pit. The heating of the checker work is accomplished by burning the but partially oxidized CO that comes from the hot ore chamber. The gas heating also makes up for the heat losses from the ore due to radiation."

Mr. Ruthenburg spoke of the practically complete elimination of sulphur in his furnace and explained

scribe a peculiar kind of scintillating phosphorescence produced in Sidot's blende by radio-active emanations. They introduced an insulated screen of sidot-blende, which had been kept in the dark for several days, in a dark space about 1 meter in cubic extent containing radio-active emanation from the soil. On maintaining the screen for two hours at a potential of -2,000 volts, it became luminous. On examining it in the dark with a magnifying glass it was seen that the luminosity was not uniformly spread over the surface, but consisted of numberless stars appearing only momentarily. With the aid of strong radio-active bodies, the scintillating phosphorescence could be made very intense. An important and characteristic distinction from the phosphorescence produced by light is that the new phosphorescence is not extinguished by red light. Blowing an air current over the screen, or pressing it against a glass plate, produced no effect upon the scintillations, and this squares well with Crookes's idea that they are the accompaniment of the projection of electrons from the screen. A calcium tungstate screen shows only ordinary phosphorescence, but a thorium oxide screen shows scintillating phosphorescence even after positive electrification.—Elster and Geitel, Phys. Zeitschr., May 1, 1903.

CHEMICAL AFFINITY AT LOW TEMPERATURES.—Having found that solid fluorine and liquid hydrogen are capable of combining at temperatures as low as -252 deg., or 21 deg. absolute. H. Moissan and J. Dewar have further studied the affinity of fluorine at -187 deg. They find that that affinity is sufficient to produce the combination of sulphur, selenium, phosphorus, or arsenic without external energy, to decompose calcium oxide with bright incandescence, and to produce the explosion of a mixture of anthracene and fluorine.—Moissan and Dewar, Comptes Rendus, March 30, 1903.

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A SIX-HUNDRED-KILOWATT GENERATOR.

THE INTERIOR OF THE HOCHFELD STATION.
A THIRTY-THOUSAND-VOLT POWER TRANSMISSION LINE.