



**HAL**  
open science

**Typological, Formal and Structural Elements of the  
Industrial Architecture of Paul Friesé. The Electricity  
Generating Stations and Sub-Stations of Paris,  
1889-1912**

Matteo Porrino

► **To cite this version:**

Matteo Porrino. Typological, Formal and Structural Elements of the Industrial Architecture of Paul Friesé. The Electricity Generating Stations and Sub-Stations of Paris, 1889-1912. Third International Congress on Construction History, Cottbus, May 2009, May 2009, Cottbus, Germany. hal-03653042

**HAL Id: hal-03653042**

**<https://hal.science/hal-03653042>**

Submitted on 29 Apr 2022

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

## Typological, Formal and Structural Elements of the Industrial Architecture of Paul Friesé. The Electricity Generating Stations and Sub-Stations of Paris, 1889-1912

Matteo Porrino

Laboratory Géométrie-Structure-Architecture – School of Architecture Paris-Malaquais, Paris, France

**ABSTRACT:** This essay relates to certain typological and formal elements of electricity power stations and sub-stations in Paris as designed by Paul Friesé (1851-1917). Despite the fact that the work of this architect was entirely informed by the rules and design templates of eclecticism, it was far from lacking architectural innovation. Indeed, throughout a career characterised by successive improvements in the spatial and functional organisation of buildings, Friesé experimented with, and adopted, a certain number of practical and structural solutions precisely at the time when scientists, technicians and industrialists were perfecting the harnessing of electric generators, the output of which had become satisfactory, to the driving force of steam engines.

“A factory, according to Pevsner’s definition, is a building of some size in which products are made in some quantity” (Pevsner 1976, p. 273). The electricity generated and supplied to private and public consumers is an industrial product as such and electricity power plants clearly belong to the family of *factories*. According to a fundamental principle, as was the case with factories, power plants were situated on the outskirts of populated areas and, where possible, near rivers. Indeed, the black smoke of the boilers, and the roar and vibration emanating from the generators would always ensure that the plants were kept at a distance from urban centres, as long as that proved to be technically possible.

The first large plant built in an urban context in Paris, right in the heart of a residential quarter, was the power station in the *Place Clichy* sector, a project by Jules Denfer and Paul Friesé, completed in 1890. This plant produced and distributed direct current over a distance of up to 2 500 m. Today, only the administrative building with its decorated façade, facing the *rue des Dames*, remains (51-53, *rue des Dames*, 17<sup>th</sup> *arrondissement*; the building has been included in the Inventory of Historical Monuments since 1992).

At first, electricity was produced only in the form of direct current and was supplied over short distances at the same tension (after the invention and development of the dynamo, industrial current became available just before 1880). Later, after the general switch over to alternating current - which, thanks to the triphase system and the use of transformers, facilitated transmission and distribution over larger distances - the plants were able to establish themselves away from towns and the network of sub-stations grew.

The last two urban power stations were the power plant of the *Compagnie parisienne de l’air comprimé* [Parisian Company for Compressed Air] of 1895, and the *Métropolitain* plant on the *rue de Bercy* dating from 1899-1904, both designed by Friesé. The plant belonging to the company *Le Triphasé* at Asnières (on the former *quai d’Asnières*, today renamed *quai Aulagnier*, Asnières-sur-Seine, Hauts-de-Seine), also constructed by Friesé between 1898 and 1901, was the first power station in the suburbs to supply a Parisian sector. (It ensured partial supply to the *Place Clichy* sector. From 1900 onwards, this sector purchased triphase current at 5 500 volt from the company *Le Triphasé*; transformation was carried out at the station on the *rue des Dames*).

During this same period, there was a rapid increase in the number of electric sub-stations, industrial relay buildings and infrastructural elements, most often urban in nature. Sited in various quarters, they redistributed high-tension alternating current from the plants in the suburbs. This they transformed into low-tension direct current, the highly stable nature of which was necessary in order to supply the *Métropolitain* network, both for the traction of the rail carriages and the lighting of the stations. Between 1903 and 1912, Friesé constructed sub-stations in Paris for the *Compagnie du chemin de fer métropolitain*, the main industrial consumer of electricity,

and for the *Compagnie parisienne de distribution d'électricité*, which provided public lighting and supplied electricity to the city's first private consumers.

The generating station in the *Place Clichy* sector took the form of a metal, brick-clad building housing the generators and machinery, located at the rear of the parcel of land, with a smaller administrative building in an eclectic style, the decorated façade of which faced the street.

The layout of the building comprised a single space divided cross-wise into two areas by the chimney. The rear of the plot was occupied by the boilers and additional space was allotted to the accumulators. The dynamos were located between the chimney, close to the switchboard, and the wall of the administrative building. A masonry chimney of a height of 48 m removed the black smoke from the boilers. In order to reduce the noise and lessen the vibrations from the horizontal piston engines, the two project architects placed them on a second structure – a roughcast metal floor, at the mezzanine level of the front building – which was detached from the perimeter walls and the skeleton of the building. Below this floor, two longitudinal corridors served as access for the coal trolleys and electric cables. The gable end of the building opposite the administrative building included a section of metal of a broad span, the arched framework of which supported the bases of the accumulators. These bases were suspended from the arch by means of rods, whilst their edging girders linked the branches of the arch together, acting as trusses on each level, (see *Pans métalliques à grande portée*, Denfer 1894, vol. 2, pp. 85-90), Figs. 1, 2.

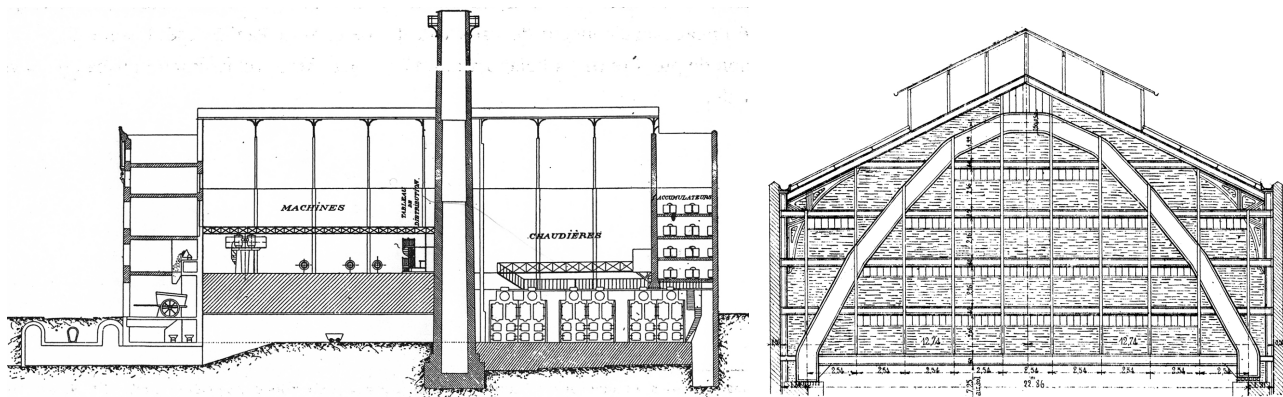


Figure 1: Plant on the *rue des Dames*. Longitudinal section; (Maréchal 1894, p. 220); Figure 2: Plant on the *rue des Dames*. Elevation of steel arch, 12 m in height with a span of 22 m, main frame work of metal section of rear gable end of the plant. One of the support units is fixed, the other is on rollers to allow for expansion; (Denfer 1894, vol. 2, p. 86)

The elevation of the front building comprised a central projecting *trompe l'oeil* element and two side wings adjoining the neighbouring buildings. The central body of the building, divided into three bays was crowned with a triangular, neo-classical pediment in terracotta pierced by an oculus, which echoed the chimney section. The three central bays of the second floor were surmounted by flattened arches – elements which in themselves were sufficient to indicate the non-residential use of the building. The architraves of the glazed bays of the first-floor, of the ground floor and above the two doors (through one of which coal was conveyed) took the form of visible metal lintels decorated with moulded rosettes - these decorative elements echoed the appearance of regularly spaced bolts which connected the exterior iron web with the interior load-bearing iron. Denfer indicates that "in many buildings, and very often in factory buildings, iron lintels were employed with the intention that they should be visible and read as part of the architectural ordering of the façade" (see *Linteaux en fer apparents*, Denfer 1894, vol. 1, pp. 284-292). The ensemble, with its rational eclecticism, drew its liveliness from the inventiveness of the ornament and the variety in brick coloration and other materials, including the coloured ceramic of the lower string course.

Neither the functional nature of the layout of the building, nor the inventiveness of its façade suffice to lend a stylistic modernity to the building complex, which remains in this regard more than ever anchored in the architectural fashions of the period, despite its innovative purpose. Nonetheless, this type of project was faced with the necessity of reassuring the inhabitants of the residential quarter where it was based and more generally those against the introduction of factories into the heart of cities. The architecture of plants, like that of substations was required to facilitate their acceptance and to reflect the commercial image of the new leasing companies.

Another notable aspect of this industrial building, its façade still today evoking the antiquated charm of times past in this corner of the quarter, is its duality. The section which housed the administrative offices and the caretaker's quarters, facing out into the public space, conceals the section at the rear housing the machinery and the boilers. Such duality is reminiscent of other types of buildings, for example, certain machine halls at the *grandes expositions*, transformed, by means of historicist stone masonry façades, into urban palaces, or railway stations with eclectic public concourses, set alongside one or more halls in iron and glass which are, however, invisible from outside. (Viollet-le-Duc posited as a favourable element a correspondence between buildings – in their use of new techniques and designs – and their era. Giving concrete form to such demands could not arise from a naive substitution of traditional elements of construction for new materials, such as, for

example metal elements. Instead it would need to develop a new structural methodology in which varying elements were brought together in a unified system which eschewed a simple juxtaposition of differing constructive elements. On another level, these same observations led him to criticize the design of the typical railway station of the 19<sup>th</sup> century, where the main building and its eclectically-designed façade contrasted with the comparative weightlessness and modernity of the iron and glass roofing over platforms situated at the rear of the main building).

In 1894, the *Compagnie parisienne de l'air comprimé*, which enjoyed one of the longest leases, began the construction of a new generating station (132-134, quai de Jemmapes, 10<sup>th</sup> *arrondissement*; the building has been included in the Inventory of Historical Monuments since 1992), with a view to reorganise its electrical distribution network.

Friesé's design responded to constraints of the plot of land, with its elongated shape running at right-angles to the Saint-Martin canal, and included a U-shaped complex housing the boilers and machinery on two levels, to which he added an administrative building lying parallel to the canal side with a façade looking out over the waterway, thus enclosing a rectangular inner court. The lack of opposition to the building within the city of a plant of this type, then considered insanitary, was probably due to the disintegration of the urban fabric of this quarter, which had been by-passed by Haussmann's large-scale renovations. Moreover, the proximity of the canal meant that coal could be transported and water for boilers pumped with ease. The small size of the parcel of land partly determined the design of the plant, which accommodated a vertical organisation of the production process; thus the machine hall occupied the ground floor and the boiler room the first floor of the building, which meant that all activity could be centred in a communal building and its functionality simplified to the greatest degree possible. This method of coupling the machinery, an apparently audacious solution, was, in fact, determined by adherence to a directive from the *Service des mines* forbidding the siting of "machinery above generators", in other words, in today's terminology, electricity generators and their steam engines should not be placed above steam generators, that is, boilers (Daumas 1980, pp. 419-420). The space beneath the curb-roof was reserved for coal bunkers and water containers.

The façade facing the canal side formed the central element of the simplified ordering which corresponded to the administrative premises and two lateral *pavillons électriques* housing the accumulators – there is only one on the left-hand side – also corresponding to the gable ends of the halls situated behind them.

The plant's exterior reflects its internal spatial division and the unity of the whole is achieved by the use of the same multi-coloured brick cladding and the bossage of the basement floor. A large iron framework with glazing distinguished the accumulator zone, whilst the visible metallic structure and masonry of the longitudinal elevation of the hall with braces in the shape of a St. Andrew's cross surmounting triangular bays (see *Pans métalliques...*, Denfer 1894, vol. 2, pp. 3, 13, 17, 20, 44), aligned itself with the artistic and technical continuity of timber-frame architecture as well as French and German *framework houses*. On the other hand, the plant had a metal frame as did the compressed air distribution building which the same company, later to become the *Société urbaine d'air comprimé – S.U.D.A.C.*, had had built by Joseph Leclair in 1891 along the *Petite Ceinture* railway track at the upstream end of the *quai de la Gare* dock (see Belhoste 1997, pp. 100-101; Daumas 1980, pp. 420-422. Put to another use, the S.U.D.A.C. factory has been included in the Inventory of Historical Monuments since 1994).

The construction of the plant at the *quai de Jemmapes* was planned to have at least four phases; the first half, on the northern side, was finished in 1896 and immediately started electrical production. Two years later, this section had been doubled and the northern half, by then completed, extended right to the rear of the site. The other part of the complex, designed to be symmetrically aligned to the first part, did not see the light of day and the power plant was never completed.

The choice of a building in two parts linked at right angles to a shorter section and completed in two successive phases corresponded with the planning of financial investments. In the particular case of the electrical industry, this was, in fact, a key factor in the management of a concern, it being the case that licences handed out by the *Conseil municipal de Paris* in 1889 and 1890 to six companies operating in the electrical sector were only awarded for the duration of eighteen years. This ensured that the companies involved chose not to carry out works the costs of which might not be repaid before the end of the contract. (Incidentally, under the terms of article 49, the new agreement of 5 September 1907, provided for "the acquisition of real estate or buildings, [and] the purchase of fixtures and fittings of all kinds in respect of the first establishment, being made and paid for by the lessees in the name of the town, becoming, *ipso facto* and immediately, the property of the latter, it being noted that the lessees should have the use of it, for the entire duration of their operation". See Malégarie 1947, pp. 191, 196.

While the company was in fact able to start production as soon as the first of the four parts was completed, the expected opportunities for further extension remained hypothetical. From 1905 onwards, the C.P.A.C. would supply its distribution sector alongside new and more powerful suburban factories.

The claim which is sometimes made, that Friesé was one of the first to design unified building complexes, the architecture of which took into consideration potential future extensions or modifications, may be partially corrected, when one considers which architectural modalities had already been in existence since the second half of the nineteenth century. The fact that many factories of the period show signs of repeated reworkings, which disturb the original architectural ordering, (the vast Creusot factories were, indeed, an example of just this, even if the organisational design of the Royal Foundry echoed that of a landed estate of the end of the 17<sup>th</sup> century, as from the date of its establishment in 1779), and that relative inability to change remained a fact of life at the end of the century, does not preclude that the classical rules of architecture or even the ide-

als of composition were quite able to accommodate potential reworkings of, extensions to, or transformations of an industrial building. This is confirmed by the architectural rules enunciated in widely-circulated works of a synthetic nature, such as the practical manual by lieutenant-colonel of the Engineering Corp, Georges-Frédéric Espitallier, the second edition of which appeared in 1912, the year of the building of the last electricity sub-station by Friesé:

On the organisation of block projects... Key rules...

Anticipating the potential extension of the plant as a whole, or of each of its parts, of each of its workshops...

... Provisions for potential extension. It may seem premature, even before the facility has been constructed and has shown its capacity, to be concerned with its future development. What would be gained, however, from having methodically designed it according to all the other rules, if after having solely addressed initial needs, unforeseen developments require expansion by means of additions, extensions and modifications, for which the same rules cannot be applied?

In order to realise the importance of such long-sighted planning, suffice it to consider what has become of certain large factories where repeated reworkings have removed any trace of the original, systematic architectural ordering and where incoherence seems to reign to the great disadvantage of its good use and manufacturing economy (Espitallier 1912, 2<sup>nd</sup> ed., pp. 25-26).

It was this principle of an architectural programme adapted to being carried out in several phases, whilst completely respecting an overall design, indeed considering the project to be an integrated whole, which would be adopted by Friesé both for the C.P.A.C. plant, and three years later, for the plant of the company *Le Triphasé* at Asnières (on the outlying factories, Cinqualbre 1988, pp. 123-134), built in two phases, according to the number of different production units.

The *Métropolitain's* power station, which was contemporary to the one at Asnières, had been planned from 1898 onwards, when the Parisian government took charge, bounded by a convention, of the construction of the complete infrastructural network (tunnels and stations), assigning to the operating leasing companies the installation of equipments, the creation of access to the stations, and the construction of power plants and sub-stations.

The recently inaugurated *Compagnie du chemin de fer métropolitain*, which had already appointed Friesé as architect, bought a rectangular site, 38 m wide and about 190 m long, near the *Gare de Lyon*, close to the Seine. The programme of works included an electricity generating station, which was to supply the third rail (motor train carriages, heating and lighting of the carriages) for the *Porte Maillot - Porte de Vincennes* line, and the administrative building for the company.

A first pavilion, standing apart from the future plant and originally allocated for use as its offices, was completed in 1899 on the *quai de la Rapée*. Eventually, between 1902 and 1904, this building was enlarged in order to house the general operating facilities, by splitting the façade - Espitallier noted its slender appearance (1912, pp. 154-155, fig. 75) - and adding the massive, picturesque lift tower with its pepper-mill roof. (This is not the place to dwell on a building of a civil nature, the architecture of which was compared with the previous experience of reconstructing the grain store of the Great mills at Corbeil, with its elevator tower designed in the manner of a military building while using the Gothicising vocabulary of the factory-castles of the Lille region and Germany).

The remainder of the plot behind the administrative pavilion, right up to the *rue de Bercy*, was occupied by the generating station, built in two phases between 1899 and 1904, (both buildings have been demolished). This was organised according to a rectangular ground-plan with five bays ten metres away from the pavilion which obscures the view from the river bank. The sole direct link between the management and the plant was a covered raised footbridge, running above the internal courtyard on the second floor.

The plant with its axis running at right angles to the Seine extended over 145 m. The internal space, like that of a basilica, was divided up into bays relating to the number of units of production. The cross-section of the design, wider than that of the plant at Asnières, shows the sub-division into five bays; the central hall was occupied by generating sets, machinery and dynamos, the side bays in their turn by the boilers which furnished them with steam, and the lower side bays by the coal bunkers. The general approach was simple and well-organised since *all the components of the same kind are laid out in one row, on the ground floor* (Fig. 3).

The metal structure of the building was brick-clad and the longitudinal elevations echoed the rhythm of the bays; around the upper section of the aisles, three circular arcades per bay recalling the clerestories of churches allowed light into the interior space. The same was true of the windows of the upper parts of the side and central bays. The façade of the lower side bays was crowned by a cornice and a brick balustrade. Over all the bays ran a roof terrace clad in volcanic cement (see *Construction des terrasses*, Espitallier 1909, 2<sup>nd</sup> ed., vol. 2, pp. 39-40).

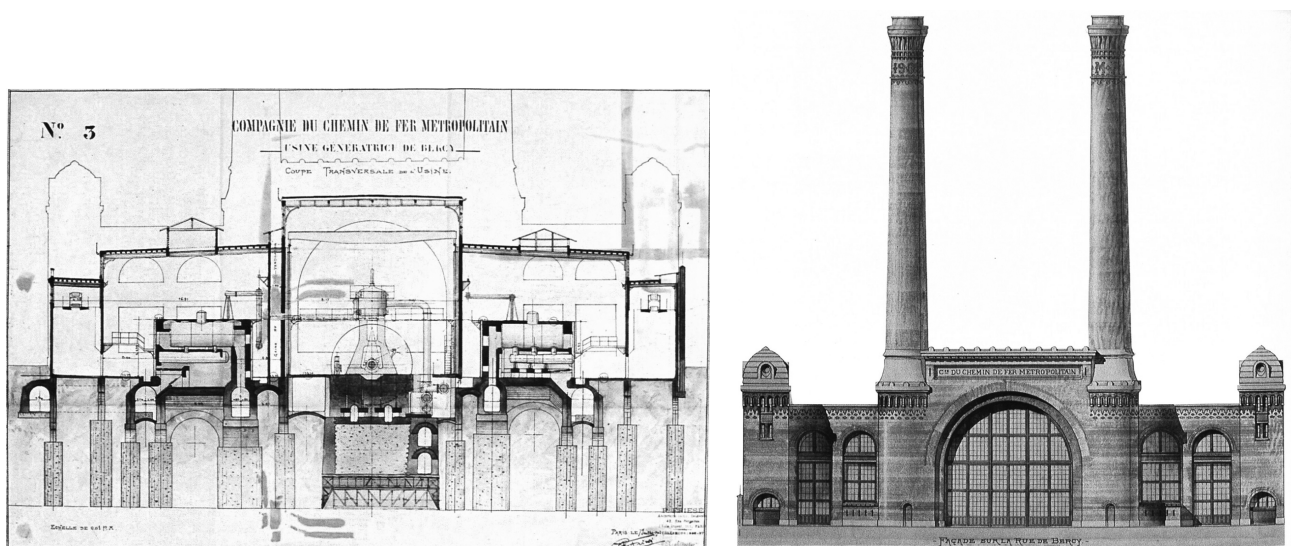
This level roofing, divided up by the varying heights of the bays and interrupted by six chimneys of 55 m in height, was a new formal element already present in the plant at Asnières, and resulted from the structural opportunity afforded by the replacement of arched or console trusses with rectilinear terrace trusses at a shallow angle. The latter comprised either iron joists clad in concrete (factory at Asnières) or girders composed of plates and angles (factory at *quai de la Rapée*; these components have variable cross-sections, through the addition of successive cover plates, forming the upper and lower girder flanges, in proportion to variations in the bending moment; this allows for load gain on the girders, repeated throughout a building made up of many similar bays), supporting the wide slabs of reinforced concrete of the roof. The adoption of this system of

roofing derived from an increase in the transverse dimensions of the last plants in comparison with those of the plant at the *rue des Dames* (couple roof and sloping sides), and of the plant at the *quai de Jemmapes* (Mansard roof). (With regard to the considerations which persuaded the architect to roof over the central nave and the lateral bays of the generating station of the *Métropolitain de Paris*, see Espitallier 1912, pp. 147-148). It also addressed functional demands, such as preventing dust deposits or making an extra storey possible, as in the case of the new service area above the central bay of the plant at Bercy (see Rozet 1904, no. 18, p. 169, fig. 5, pl. 29).

The two gable ends, facing the internal street and the *rue de Bercy*, are not identical; one can observe a certain discrepancy in the design of the project, and the drawings of the main façades make plain the different phases of construction (the machine hall and two thirds of one of the boiler rooms were built to begin with, followed by the other half of the machine hall, and finally the last third of the boiler room and an extra room, of the same size, again as boiler space).

"[...] a plant of this kind was something new and it was only gradually, as the work progressed and as it became clear which needs had to be addressed, that the management was able to give [...] indications for the programme of works, the beginning of which they could see well enough, but could not envision the final destination" (Rozet 1904, no. 17, p. 158). Nonetheless, and such was the intention of the architect working in its service to the best of his abilities, the general thrust of the composition was respected and its unified character maintained, as can be seen clearly from the plans which might have well been conceived in an integrated fashion from the outset.

The first façade set up a dialogue with the administrative building, echoing to a less extent its Gothicising style. The type of facing overlooking the public space of the *rue de Bercy*, was innovative. Its symmetry was given rhythm by the interplay of the differing heights of the chimneys, which participate in the composition on the main plane and of the two side turrets, and by the adjoining boiler bays recessed with respect to the main plane. The absence of ornament flattens the surfaces and lends a geometrical quality to the volumes. The building therefore appears reduced to essentials, almost monumental (Fig. 4).



Figures 3, 4: Plant on the *rue de Bercy*. Cross section and elevation of the façade; (Drawings, P. Friesé, 1903, Archives of the City of Paris)

This dichotomy, expressly sought by the architect, is linked to a consideration of how this type of industrial building can be expressed in an urban context: its inspiration is drawn, the author believes, from the search for a typology characteristic of the power plant, summarised here in the architecture of the façade overlooking the *rue de Bercy*.

The *Onze-Lieve-Vrouwebasiliek* in Maastricht, or some medieval gates, such as the *Marschiertor* in Aix-la-Chapelle might be considered as distant formal sources for this façade. It is also somewhat reminiscent of the silhouette of the coeval monumental gate sketched by Binet for the entrance to the *place de la Concorde* for the Universal Exhibition of 1900. The building for the *Papeterie d'Essonnes* by Denfer, which was pierced at the gable end by a large bay providing deep light penetration and closed by a metal frame with glazing, is another plausible reference.

The idea of integrating the body of the two chimneys, which rise skywards as part of the stone masonry façade, may have been inspired by observing certain types of architecture from the Lille region, (around 1900, Friesé completed the electric traction factory at Armentières in the *Nord* for the company *Omnium Lyonnais*). There, the superimposing of two elements was, so to speak, pushed to its logical consequences, and their interrelation might lead, for example, to the reiteration of the design of the façade on the cylindrical volumes of a chimney, or even to the siting of one of the staircases around the chimney's circumference, a totally characteristic solution motivated by the desire to distance the vertical interconnections from the centre of the main building as much as possible, with a view to prevent the spread of fire (stairway detached from the body of

the main building, stairway protected inside a tower, or stairway wrapped around the chimney). The chimneys and the towers of the *Motte-Bossut & C<sup>ie</sup>* or *Désiré Wibeaux-Florin* spinning-mills at Roubaix illustrate this (Grenier 1979, pp. 114-119, 129).

In this way, Friesé reworked the formal nature of the first power plants; the siting of the machinery, installed behind the large, central, glazed bay with its semi-circular arch, gave expression in a theatrical manner to the theme of the power of the machine and the new electrical industry: the façades and the chimneys are delicately decorated with polychrome bricks, conforming to Flemish and Dutch usage. The coal turrets at the side of the building, placed on the four piers of a passage acting as a portico, were crowned with cement cupolas reminiscent of stair towers used in the contemporary architecture of Hendrik Petrus Berlage. Finally, the functionalist message of this simplified façade lessened in part the sense of rupture in the urban fabric caused by the dominating presence of the power plant.

The clarity which Berlage accorded to his architectural designs stemmed from his analysis of medieval, Romanesque and Gothic forms. If his rationalism might be considered a direct descendant of Viollet-le-Duc, in practice, he was an innovator. Each of his decorative designs is resolved by combining different materials for the various structural elements, that is to say, by the variety in their chromatic values in relation to the different openings of the façades and volumes of the whole. As in the work of Berlage, Friesé's historical referencing in his plant at Bercy is the point of departure for a structural and formal analysis. The other aspect these architects have in common is the influence exercised on them by the Expressionism of the American, Henry Hobson Richardson, who was a generation older than them and whose architecture is inspired from the Neo-Romanesque element in the work of Léon Vaudoyer, (massive walls in rough stone, small openings either isolated or paired rhythmically, bossage decoration).

The plant at Bercy was not yet finished when on 19 July 1900, the first line of the Paris *Métropolitain* was put discreetly into service. Whilst the work was in progress, the current supplied by the plants on the outskirts was conveyed as alternating triphase current at 5 000 volt to the three sub-stations, *Etoile*, *Louvre* and *Nation*, where it was transformed into direct current at 600 or 550 volt, which was more stable and preferable for the security of consumers, but involved more loss of supply than alternating current.

Aside from machines for transforming primary current, sub-stations housed accumulator batteries which functioned as buffers. Also present in power stations, they stored electrical energy in order to restore it when the network demanded more power (the demand, in fact, varied at all times – starting of carriages, train full of passengers, train climbing up a slope).

During the first quarter of the twentieth century, there was an increase in the number of electrical sub-stations, which took the output of the new power plants on the outskirts. Aside from the *Métro* lines, they supplied consumers, both private and public, thus ensuring electrical distribution in the city.

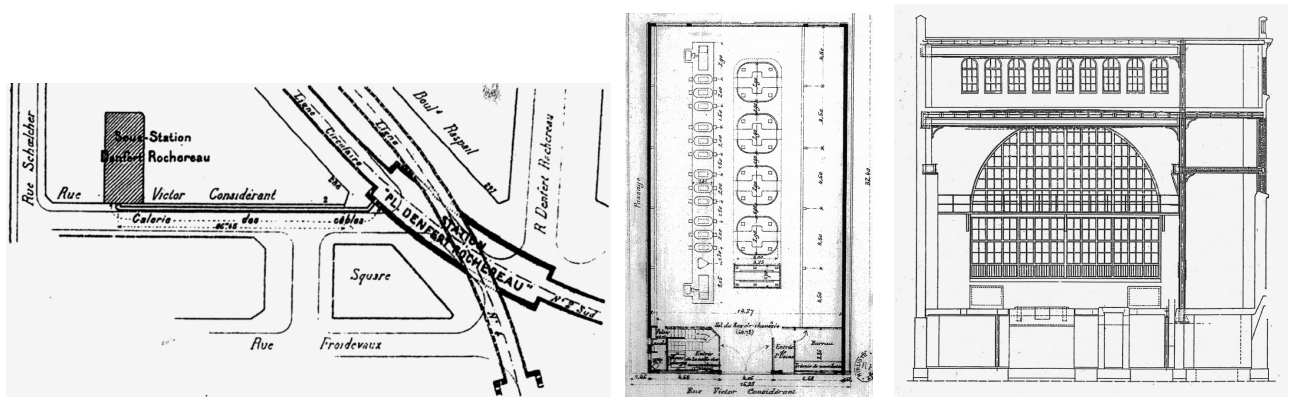
From 1902, la *Compagnie du métropolitain* started building transformer stations to supply new lines, and from 1908, the *C.P.D.E.*, which was then reorganising its system of distribution, inaugurated a programme of works for the construction of transformer stations in all sectors. The architect Friesé was commissioned by these two companies to develop projects on which he worked for about ten years.

These buildings, the typology of which crystallised around a rather simple, functional design with the same structural organisation, were to be found in at least two variants, related to the formal solutions Friesé adopted for his façades. In fact, each sub-station comprised a machine hall on the ground floor and an area for the accumulators on the first floor. From the structural point of view, one can see the repetition of a steel load-bearing structure, the ordering of which is visible through a translucent section, in iron and glass, in the façade. Roofing generally takes the form of a roof terrace.

Façades vary according to the designs worked out for each of the two commissioning companies. This gave the two families of buildings individual identities and provided each company with a commercial image.

The *Métropolitain* sub-stations, which were smaller, were modelled on the *Opéra* sub-station, the first one designed by Friesé, which dates from 1903-1904 (41, rue Caumartin, included in the Inventory of Historical Monuments in 1992). Their façades, comprising a curtain wall in iron and stucco, were divided along their entire width into three bays unified above by flattened arches and a cornice. An attic storey crowned the ensemble allowing for an extra storey above the sub-stations.

The other *Métro* sub-stations still extant are La Motte-Piquet (135, boulevard de Grenelle), 1906; Denfert-Rochereau (10, rue Victor Considérant), 1906 (Figs. 5, 6); République (3, rue Rampon), 1908; Cité (19, rue Chanoinesse), 1909; Villette (76, rue de l'Aqueduc), 1909-1910; Bastille (31, boulevard Bourdon), 1911 and Auteuil (2 bis, rue Michel-Ange), 1912, both included in the Inventory of Historical Monuments in 1992.



Figures 5, 6: Sub-station Denfert-Rochereau, location plan and ground floor plan; (Hervieu 1907, col. 5; pl. 2), Figure 7: Cross-section of the Bastille sub-station; (R.A.T.P. - Paris, Micrographic service)

The prototype of sub-stations for electrical distribution was the Voltaire sub-station (14, avenue Parmentier), which dates from 1908. Their façades, richer and more elegant than those of the *Métropolitain*, were framed by lateral masonry pilasters which, in the larger sub-stations were enlarged to form stair turrets. The design, including a transparent section in the façade and its division into three, was always retained, but here the ensemble is softened by the addition of semi-circular arches in two superimposed orders, the second one relating to the accumulator storey. Each of the three triple-height bays of the main hall is topped by a tripartite bay and the ensemble of bays and turrets is crowned with a cornice on brackets.

The other C.P.D.E. sub-stations still in existence are Temple (36, rue Jacques Louvel-Tessier), 1908, included from 1992 in the Inventory of Historical Monuments; Saint-Roch (26, rue Saint-Roch), 1908; Sèvres (6, rue Récamier), 1910, which was restored in 1990, has housed since then l'Espace Fondation EDF. (On the organisation of distribution and the state of sub-stations between 1907 and 1913, see Malégarie 1947, pp. 56-60).

The limited nature of this article does not permit for an analysis of each of the buildings, nor for a more precise examination of the two families of sub-stations built up until 1912; (the sub-station Saint-Roch, built by D. de Pénanrun in 1893 [see Friesé 1908, pp. 409-410], and the sub-station Sévigné, in the Marais, destroyed, which was the result of the conversion, in 1908, of a town house dating from the XVII<sup>th</sup> century, are exceptions).

The main electrical sub-station in this series of projects, the Bastille sub-station, built for the *Compagnie du Métropolitain* in 1911, should be seen rather as a monumental variant of this type of buildings than as their typological and formal culmination. The main façade of this sub-station, which is surrounded by three streets, faces onto the boulevard running parallel to the Arsenal dock, whilst its rear façade stands on the *rue de l' Arsenal*. Both of these façades are pierced by glazed arcades of 12 m in height, between side pilasters, on which arched openings are aligned. The building, supported by a metal structure (Fig. 7) is entirely clad in sand-lime bricks of a light grey colour, and a crowning balustrade protects the roof terrace. The masonry and the two orders of openings one above the other, lend the main façade the appearance of a Roman aqueduct and its bays. Two unsymmetrical stair turrets place emphasis on the corners of the station with the street at right angles to the canal; these elements and the pilasters strips above the arcades, which linked the blind arch frieze to the articulation of the windows of the first floor, remind us that the architect's primary artistic reference for this building complex is the German Neo-Romanesque (expressed in a personal interpretation of the *Rundbogenstil*), and perhaps certain infrastructural Parisian buildings with a regional character, such as the reservoirs of Montmartre by the architect Diet, dating from 1889.

## CONCLUSIONS

The designs for power plants and sub-stations were determined by precise functional and technical imperatives (organisation of the area of production and the siting of machinery, resistance of structures to load and vibrations, lighting conditions and ventilation, fire safety precautions, reduction in noise and smoke emissions), and by a general financial principal (planning, sub-division of the space into units of production); industrial projects in an urban context nevertheless provided opportunities for architects to experiment during this period of transition, when they were required to resolve partially new problems of construction and composition.

One should further note that, as in the cases of Cremer and Wolffenstein in Berlin or English architects and engineers who applied themselves to problems related to the building of power plants and electric sub-stations, the work of Denfer and Friesé is inseparable from the architectural and urban changes engendered by the universal exhibitions of the last decades of the nineteenth century – the Parisian exhibitions which were held after the fall of the Empire, or the American exhibitions held in Philadelphia and Chicago.

Without breaking the mould of the eclectic culture of their era and thanks to what a number of them had learned from the experience gained in civic programmes of works, what these architects contributed to the renewal of architectural forms for industrial building was considerable. (These architects initially worked in the field of civil architecture, before establishing close links with industrial investors. This was the case for Friesé, who met Auguste Lalance in 1890, followed by Empain and Schneider, who were to be behind many of the commissions for electricity power stations and sub-stations).



The adaptation of architectural forms to technological changes in the field of electro-technology, to the new siting of machinery or to the reduction in its size – or even to the advances displayed at the specialised exhibitions in Paris in 1881 and in Frankfurt in 1891 – is an aspect which also deserves note.

As far as the development of electro-technology is concerned, in an initial phase which lasted up until the end of the century – during which English and American technicians were amongst the most inventive – practice was in advance of theory and empirical methods were frequently adopted. Developments in theoretical physics during the first quarter of the twentieth century allowed, in a second phase, the rapid increase in power and output from generators and the greater efficiency and reliability of transformers, which greatly reduced in size.

The technology behind thermal power plants was also in full development at the time. Until 1900, the only industrial engine was the alternative piston steam engine, which drove dynamos or alternators. Later on, the turbine engine made it possible to build groups of much faster and more powerful turbo-alternators. At the same time, one went from old-style boilers of *locomotive* type to improved steam generators with a greater capacity for production, mechanisation of handling and surface condensation.

With the general change-over to alternating current – which thanks to the triphase system and the use of transformers allowed transmission and distribution to be achieved over longer distances – generating stations moved away from town for ever and the network of sub-stations and transformer stations was extended. However, the dimensions of these buildings continued to reduce and the architectural question about their insertion into the urban context all but ceased to be posed. Sub-stations, which were originally manned and supervised by staff, finally turned into self-sufficient structures, overseen and regulated at a distance, and visited periodically for maintenance. (In this regard, see, for example, the picture of a modern transformer station at the *Exposition des Arts décoratifs* of 1925, in P. Léon, *Rapport général...*, Paris, 1928).

Finally, the author would like to stress the fact that the architects active at that time in the field of industrial building belong to the eclectic and modern environment. Indeed, aside from the fact that they were perfectly integrated into society and the artistic and technological context of their time, their relative proximity to today's culture facilitates the reading and interpretation of their architectural endeavours, and, via evidence of eclecticism pushed to its extreme consequences, it is possible to catch a glimpse of an imminent move towards a new methodology and a new architectural culture of an eminently international nature.

His association with the engineer and professor of the *École Centrale*, Jules Denfer, between 1885 and 1891, allowed Friesé, awarded a diploma in the architectural section of the *École des Beaux-Arts* (atelier of Ernest Coquart), to perfect the art of construction and to learn the technique of building in metal – given an exceptional showcase by the exhibitions of 1889 and 1900. Engineers being notorious at that time for the bad quality of their designs, the respective skills of the two associates complemented one another.

The practice projects and then those of Friesé alone bear testament to the plurality of styles they used over a period of thirty years, whether for civil or industrial architecture.

This aspect of eclectic practice led to a shift in the relationship between the development of the project and its phase of execution, which resulted progressively in a separation of architectural composition and building technology.

Based on univocal scientific rules, technology could not take off in multiple directions in order to follow a plurality of styles. The concept of style was, therefore, implicitly limited to referencing designs for the decorative facing of buildings.

This dichotomy, characteristic of the period, was in some ways embodied in the Denfer-Friesé association, and more generally in the collaborative work between architects and engineers, a formula which responded to the demands of industrial society.

The historicist experience should, nonetheless, be evaluated according to another perspective, which also takes into account the balance which established itself between theory and practice, and not just the various urgent demands, which within the context of such rapid changes – exemplified by the development of public transport and the *métro*, with their transformation of the city and unification of the country – were exercised from outside. (After the inception of electric railway lines – made possible by the development of electric traction – works commenced for the construction of the first underground lines. Between 1887 and 1890, the *City and South London* was constructed in London, and in 1902 the *Untergrundbahn* was opened in Berlin).

Historicism, which repeatedly opts for formalist solutions, upholds the separation between problems relating to form and problems of technology. This expedient allowed a number of the problems posed to be addressed and the art of construction to progress by sector, according to the analytical methods of contemporary culture, and encouraged architects to see that the forms of historical architecture needed to be adapted to new conditions.

It was precisely this context which laid the foundation for the modern movement, and the contradictions inherent to historicism were exactly the aspects around which the problematic of the new architecture was worked out.

The work of these architects and engineers can, therefore, be seen as the foreshadowing of an architectural modernity, still hazy at the time but nonetheless discernible in the new forms of functional design and the less adorned façades. And whilst Friesé, a contemporary of Anatole de Baudot, did not have recourse until later in his career to the technologies of reinforced concrete (the Charles Six Spinning Mill at Tourcoing de Hennebique dates from 1895, and it was not until 1912, when the Hennebique Company executed part of the work, that Friesé made use of mushroom slabs for the floor of the Diamalt Factory at Ris-Orangis), his purely eclectic practice stood as a precedent for other pre-war architectural endeavours, such as pre-modern architecture

which took form in the industrial buildings by Gropius, Meyer, Behrens and Poelzig, and in the factories by the Americans, Ernest Ransome and Albert Kahn.

## REFERENCES

- Belhoste, J.-F.; Smith, P. (eds), 1997: *Patrimoine industriel, cinquante sites en France*. Paris: Éditions du patrimoine.
- Boileau, L.-C., 1900: L'usine du métropolitain de Paris, architecte : M. Friesé. *L'Architecture* 45, pp. 399-403; Deux autres usines d'électricité, par M. Friesé. 46, pp. 409-415.
- Caron, F.; Cardot, F. (ed.), 1991: *Histoire générale de l'électricité en France, vol. 1, Espoirs et conquêtes, 1881-1918*. Paris: Fayard.
- Cinqualbre, O. (ed.), 1988: *Architectures d'usines en Val-de-Marne, Cahiers de l'Inventaire 12*. Paris: Inventaire général des monuments.
- Culot, M.; Foucart, B. (eds), 1992: *Architectures de l'électricité*. Paris: Norma.
- Daumas, M., 1980: *L'archéologie industrielle en France*. Paris: Robert Laffont.
- Denfer, J., 1891-1897: *Architecture et constructions civiles...* Paris: Baudry.
- Denfer, J., 1894: *Charpente métallique, menuiserie en fer et serrurerie*. Paris: Gauthier-Villars et fils.
- Dumas, A., 1901: Le Métropolitain de Paris. Exploitation des lignes en service. Usine électrique de Bercy. *Le Génie Civil*, vol. XXXVIII, no. 18, pp. 277-293.
- Espitallier, G., 1909 (2<sup>nd</sup> ed.): *Béton armé, Livre II, Compléments et applications*. Paris: École spéciale des travaux publics.
- Espitallier, G., 1912 (2<sup>nd</sup> ed.): *Construction des usines et des établissements industriels*. Paris: École spéciale des travaux publics.
- Fiblec, H., 1991: *Paul Friesé, 1851-1917*. Paris: Norma.
- Forthuny, P., 1910: Dix années d'architecture. Les demeures du travail depuis 1900. *La Gazette des Beaux-Arts*, vol. III, pp. 429-430.
- Friesé, P., 1908: Isolement d'un bâtiment par sciage. *L'Architecture* 50, pp. 409-410.
- Grenier, L.; Wieser-Benedetti, H., 1979: Les châteaux de l'industrie. Recherches sur l'architecture de la région illoise de 1830 à 1930. Paris-Bruxelles: Archives d'architecture moderne.
- Hallsted-Baumert, S.; Gasnault, F.; H. Zuber (eds), 1997: *Méto-Cité. Le chemin de fer métropolitain à la conquête de Paris, 1871-1945*. Paris: Paris Musées.
- Hervieu, J., 1907: Le Chemin de fer Métropolitain de Paris. Ligne circulaire n. 2 Sud (suite). Distribution électrique. *Les Nouvelles Annales de la Construction* 625, col. 1-7.
- Journet, F., 1897: Les nouvelles installations électriques de la Compagnie Parisienne de l'Air comprimé. *Le Génie Civil*, vol. XXXII, no. 7, pp. 105-114 ; no. 8, pp. 125-131.
- Kerdomaz, L., 1905: A propos du Concours de Façades. *La Construction Pratique* 26, pp. 418-421.
- Lassaux, H., 1903: Usine électrique du métropolitain à Bercy. *La Construction Moderne*, 21 March, pp. 293-294; 28 March, p. 305.
- Lencauchez, J.-A., 1906: Foyers mécaniques des usines électriques de Bercy (Paris) et de Vitry (Seine). *Le Génie Civil*, vol. XLIX, no. 26, pp. 413-416.
- Malégarie, C., 1947: *L'électricité à Paris*. Paris-Liège: Béranger.
- Maréchal, H., 1894: *L'éclairage à Paris*. Paris: Baudry & Cie.
- Mittmann, E., 1994: Architecture de l'industrie électrique et cadre urbain. La confrontation entre la France et l'Allemagne. *Bulletin d'histoire de l'électricité* 24, pp. 43-64.
- Monmory, F., 1890: Bâtiment d'administration du secteur de Clichy. *La Semaine des Constructeurs*, II<sup>nd</sup> series, year 5, no. 6, pp. 65-67.
- Moriès, L., 1900: Usine électrique de la Compagnie Le Triphasé à Asnières (Seine). *Le Génie Civil*, vol. XXXVII, no. 6, pp. 89-97.
- Pevsner, N., 1976-1989: *A history of building types*. Princeton, N.J.: Princeton University Press.
- Rivoalen, E., 1891: Usine de la Société d'éclairage électrique du Secteur de la Place Clichy à Paris. *Les Nouvelles Annales de la Construction*, vol. VIII, cols. 6-9.
- Rozet, G., 1904: Usine génératrice pour le Métropolitain de Paris. *L'Architecture* 17, pp. 157-161 ; 18, pp. 168-171.