Metro line No.1 in Budapest

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***Abstract* — In the second half of the 19th century Budapest (Hungary) became a metropolis. Huge infrastructural investments formed the city into the present tourist-luring townscape. In 1896 the country celebrated the thousand year anniversary of the statehood and the mayor's office wanted to raise the glare of the feast with an up-to-date technical solution. Up to that time horse carts, horse tramways electric tramways, etc. were used for transportation. The new elegant avenue rimmed with palaces connected the center and the city park where a millennia world fair was organized.**

For the establishment of the fast and posh connection an idea was formed to push the tram line underground. In 1894 a tender was created for the realization of the first continental underground electric tramline. The construction was realized in 21 months by the local entrepreneur *Robert Wünsch*, the bogie carriages were produced by *Schlick Forgery and Machine Factory*, and the electric devices were made by *Siemens und Halske Co.* The steel and concrete structure stations were tiled by artistic tiles of the *Zsolnay* factory.

The Budapest metro line No. 1 has been in operation since its inauguration, its 120 year anniversary will be held in 2016. The Underground Railway Museum (URM) with tree original wagons has been open to the public in a non-used tunnel part since 1975. The Budapest metro line No.1.became part of the World heritage in 2002, together with the avenue above it called "*Andrássy street*".

The Budapest metro is a candidate for becoming an IEEE milestone.

Keywords: First electric metro line in continental Europe, Budapest millennia, fast construction, in operation for 120 years

I. General history

The first underground line in the world the London metro was powered by steam engine. It was changed to electric only a decade later, in 1907. The really first electrical underground metro in the world is the London Underground that began electric services operation using a fourth rail system in 1890 on the City and South London Railway (C&SLR), now part of the Northern line, between Stockwell and King William Street station. The Glasgow metro (UK) was inaugurated on December 14th, 1896, it was powered by a clutch-and-cable system, with one cable for each direction. The cable was driven from a steam-powered plant. The prime-metro of Chicago began revenue service on June 6th of 1892 by a small steam locomotive pulling four wooden coaches. In 1893, trains began running on the Lake Street Elevated Railroad and in 1895 on the Metropolitan West Side Elevated. The Metropolitan was the United States' first non-exhibition rapid transit system powered by electric traction motors. But it wasn't underground…

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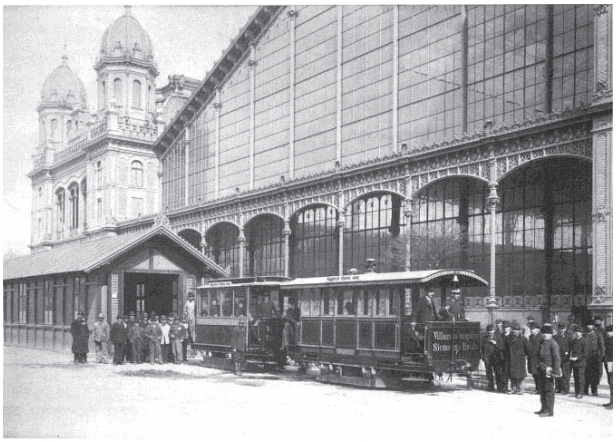

Fig. 1.: The *Siemens & Halske* tram in 1887 in Budapest [6]

Fig. 2.: The lower current collector system in the Budapest Transportation Museum (Varga Ákos Endre – [8])

The monopolistic horse pulled tramway service company *Budapesti Közúti Vaspálya Társaság* (BKVT) had operated with 700 horses since 1860 but was not open for innovations. In 1887 a 1000 m track was been built by *Siemens & Halske* for electric tram (Fig.1.) with lower current collector (sunken below the surface – see Fig.2.). It was named *"Budapest system"* but its reliability was not too high because dirt could fall into the small ditch. Later this system was applied in Vienna and in Berlin, too. For electricity supply a power plant was set up in "Akácfa street" by 3 pieces 100 HP steam turbine driven generators with 300 V DC.

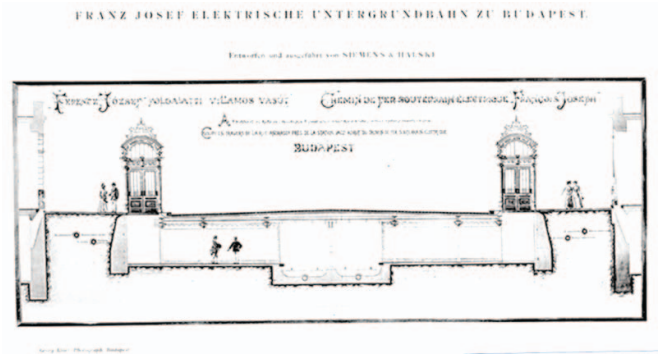

Fig. 3.: Plan of the cross section (by György Klösz)

In 1875 a new representative avenue was built between the center and the city park. For esthetic reasons no horse-pulled or electric tram line construction was allowed in this street. Closing the date of the celebration of 1000 years old Hungarian Kingdom (Millenia in 1896) the decision makers were pressed to seek for appropriate mass transport solutions to the celebrations' site in the city park (Fig.3.). The idea of the underground came from Mór Balázs who did an excellent job in the management of the project. He received nobleness for his activity and his coats of arms contained the motives of the underground train, too. In January of 1894 a tender was issued to solve the problem by an electric underground tram. This was a joint action by the two competitors: *Budapesti Villamos Városi Vasút (BVVV – Budapest City Electric Train Company)* and *Budapesti Közúti Vaspálya Társasággal (BKVT – Budapest Municipal Train Company)*. The decision was made on 9th of August, 1894. The tunnel and stations were built by entrepreneur *Robert Wünsch*, the bogie carriages wereproduced by *Schlick Vasöntöde és Gépgyár (Schlick Forgery and Machine Factory)*, and the electric devices were made by *Siemens und Halske Co.*

Fig. 4.: Tunnel digging (by György Klösz)

Fig. 5.: Construction of the station "Arena street" (fortepan.hu)

The first electricity driven metro line in the continent (2nd in the world) was inaugurated on 2nd of May 1896 in the presence of Franz Joseph – Kaiser of the Austro-Hungarian Empire. On 8th of May Franz Joseph travelled on the whole line (Fig6.). This royal course was driven by the great-great grandfather of the author. The operating company was also renamed from *Budapest Underground Electric Railway Company* to *Franz Josef Underground Electric Railway Company.* During the remaining 8 months of 1896 the metro carried 3 million passengers. This number rose to 11 million by 1917. The operating hours were between 6 AM and 11 PM with 4 min succession slots.

Fig. 6.: Memorial tablet of the inauguration (URM)

After World War II in 1949 the *Fővárosi Villamos Közlekedési Vállalat (FVKV – Municipial Electric Tramway Company)* took over the operation of *'underground railway'* (in this time the name wasn't *'metro'* but *'underground'* or *'Milleneum underground'*). In 1959 additional 16 pieces of second-cars were constructed with driver seat. In these years 1% of the mass transportation of the capital was handled by this line.

Budapest has nowadays 4 metro lines, the last one was opened in 2014. The historic metro line No.1. (called *'yellow line'* after the color of the carriages) is in good shape, plays an important role in urban traffic. More than 300 trips transport the 10 to 35 thousands passengers daily between the 11 stations. The Budapest metro line No.1.has been part of the World heritage since 2002 together with the avenue above it called "*Andrássy Road*".

II. The Tunnel

The tunnel was made by "dig and cover" technique and the work was performed in two shifts with man and horse power (Fig.4.). At the night shift electrical arc lightings were used. A total of 138,000 cubic meters of soil were excavated by hand, and 47,000 cubic meters of cement and 3,000 tons of iron were required for the support structure (Fig.5.). The leaking water was trapped into collecting wells and was pumped up by electric suction pumps. The construction works (3.22km tunnels with 9 stops and 0.46 km line on the surface with 2 stops) were finished on time in the frame of the previously determined budget. The inner height of the tunnel is 2,65 m (3,5 m till the surface), it is limited by the crossing of the main sewage canal. The average width is 6 m (Fig7.).

During the construction new materials were used. The concrete strengthened by iron was the invention of *Robert Wünsch*. The tunnel walls, the slab and a small bridge are built of ferroconcrete. The concrete was mixed by electrical mixers.

Fig. 7.: Tunnel start at Vörösmarty street station

III. Carriages

The initial common fleet of the two operators consisted of 10 yellow metal covered carriages of *Budapesti Villamos Városi Vasút (BVVV)* and 10 brown wood covered railway carriages of *Budapesti Közúti Vaspálya Társaság (BKVT)*. The royal carriage No. 20. had extra solutions with a saloon. It was used by Kaiser Franz Joseph, King Carl IV., Kaiser Wilhelm, etc.

Each railcar could accommodate 28 seated and 14 standing passengers.

The original metal coated railcars had 11,77 kW LDo motors with Gall-chain for driving 650 mm diameter wheels.

The old wood covering rail cars had 14,71 kW B 22/30 motors mounted on wheel-set axles with 800 mm diameter wheels (Fig.8.).

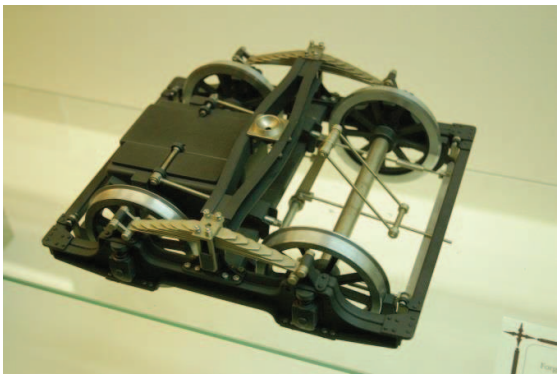

Fig. 8.: Model of bogie of the railcar No. 20 in 1896, wheel diameter 800 mm (URM).

Nowadays 5 examples exist from the original fleet (see Table.I.)

Table I.: List of existing old carriages

No.	*description*	*location*
1	the only remaining metal covered carriage (Fig.9.)	Underground Museum Budapest
11	wood covered Nostalgia carriage	in operation Budapest
12	wood covered	Hannover tram museum, Wehmingen, Germany
18	wood covered	Seashore Trolley Museum, Kennebunkport, ME USA
19	wood covered (Fig.10.)	Underground Museum Budapest

Fig. 9.: Historic metal covered carriage No.1. (UMR)

Fig. 10.: Historic wood covered carriage No.19. and a trailer No.81. (UMR)

Between 1924 and 1930 the motorcars were overhauled. The simple sliding doors were doubled and got pneumatic drives, the bogies were enlarged, instead of 16-20 HP motors larger 60 HP power motors were built in (TR 4,5). From 1960 trailer carriages were added, too (Fig.10.).

After 75 years of operation from 1971-73 and 1987 the railcars were changed. The new 23 tripartite railcars were designed and build by the Hungarian Ganz Villamossági Művek (Ganz Electrical Works) and Ganz-MÁVAG (Ganz Hungarian General Wagon and Machinery Factory) in Budapest, Hungary (Fig.11. and 12.). The Ganz articulated railcar available for 190 passengers is tracked by four 66 kW TK44 A type hauling motors. Nominal speed is 60 km/h. Total length is 30.37 m , weight is 37 tons, the wheels' diameter is 670 mm.

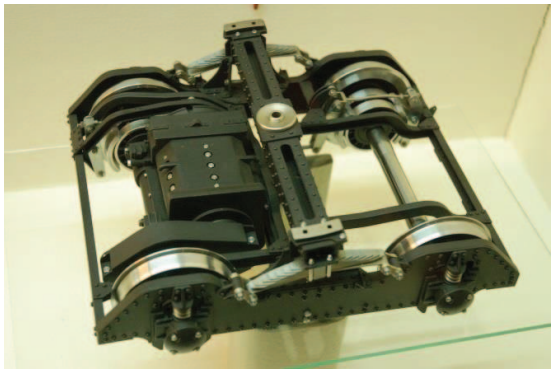

Fig. 11. Model of bogie of the railcars built in the 70ties (URM)

Fig. 12.: The Ganz articulated railcar

IV. STATIONS

The line has 8 original and 3 newly made underground stations (see Table II.). Above the underground station attractive entrance halls designed by *György Brüggeman* and *"Schickendanz et Herczog"* were erected. Unfortunately these halls can't be seen anymore.

The walls of the 8 old stations are covered by porcelain ceramics produced by the *Zsolnay Factory* in Pécs, Hungary. The ferroconcrete ceiling is supported by riveted iron pillars. In 1995 the stations were renovated, fixed, insulated and dyed by anticorrosive painting.

Table II.: List of stops

journey time in min	stops	remarks
0	Vörösmarty tér	Gizella square (nowadays Vörösmarty square)
1	Deák Ferenc tér	Deák Ferenc square
2	Bajcsy-Zsilinszky út	Váczi avenue (nowadays Bajcsy-Zsilinszky avenue)
3	Opera	Opera (Fig. 13. and 14.)
4	Oktogon	Oktogon square
5	Vörösmarty utca	Vörösmarty street
6	Kodály körönd	Körönd (Kodály roundabout)
7	Bajza utca	Bajza street
8	Hősök tere	Aréna street (nowadays Heroes' sqare)
9	Széchenyi fürdő	Zoo (surface section - abandoned)
11	Mexikói út – new underground terminal	Artézi bath (surface section – abandoned, nowadays Széchenyi bath)

Fig. 13.: Downstairs to Opera station and iron capital

Fig. 14.: The Opera station

V. TRACK

The 1435 mm gauge track was built from iron cross-ties *'Banovits system'* containing asymmetric *Vignoles* rails (24,2 kg/m) that were connected with lap-seams (patent of *Hartman*). This solution provided noiseless traffic not to disturb the promenade on the surface, the inhabitants and it saved the motors.

The *Siemens-Halske* signalization system showed red light if a train was in the next tunnel section. Free way was signalized by white light.

In 1995 the rails were changed to 48kg/m *Vignoles* rails (Fig.14), the old wooden sleeps were re-sleepered by concrete holders (makes more noise).

Fig. 15.: Train arriving at the Kodály Körönd station

VI. POWER SUPPLY

In an early plan three rails were designed for lower current collector, but this idea was later abandoned. The 350 V DC hauling current was generated in the *'Kertész utca – Gartner strasse' (Akácfa utca)* power station. The overhead supply was solved by 50 mm height two-pole double rails (used in mines). In the twenties the supply voltage was raised to 550 V DC (nom. 600 V) and the double upper feeder rails was changed to a similar, single feeder rail with single pole feeding and lower rail feed-back (Fig. 16.).

Fig. 16.: The old and actual upper power supply rails

VII. RENEWALS

In the 20's important reconstruction works were made. In the frame of this up-dating the chassis and the safety devices were changed. Also the bogies and the motors were enlarged. The boarding doors were widened and the voltage level of the power supply was raised to 550 V DC, like at all the other 'surface' trams.

At the beginning of the seventies the emerging traffic of Budapest, the connection to the new metro line No.2. and the aged old line required further renovation. For the 100th anniversary of the unification of Buda, Pest and Óbuda (birthday of Budapest) the metro line No.1. was rejuvenated.

In the reconstruction process the tracks, electricity system, carriages were changed. Also the tunnel, the stations were renewed in its original artistic design. The traffic changed from the original 'keep to left' to the 'keep to right'. For housing a new, larger shed was built on a new site.

Two new stations were erected and the former non underground section was pushed down to new tunnel. From the fifties a 40 m long part of the old tunnel was separated and closed. In 1973 it was converted into the museum of the first Budapest underground metro (Fig.17.).

Fig. 17.: In the Underground Railway Museum

In 1996 the line celebrated its centenary. In a reconstruction program initiated by the Municipality of Budapest starting in 1993 the following areas were tackled:

- Reconstruction of the permanent way using a reinforced concrete bedding with flexible fastening and welded rails
- Reinforcing the roof of the tunnel and stations
- Overhauling the architectural, interior decoration and mechanical systems of stations
- Modernizing the electrical systems, the passenger safety and railway signaling systems, installing new safety features

VIII. CONCLUSION

The Budapest metro has been the first commercial electrified underground train in the European continent since 1896. The successful realization took only 21 months. It included several technological innovations from the turn of the 20th century. The memories of early underground transportation have been carefully preserved for the future. The Budapest metro is a candidate for becoming an IEEE milestone.

IX. REFERENCES

[1] The Chigao "L"; https://en.wikipedia.org/wiki/Chicago_%22L%22

[2] Miklós Merczi: Underground Railway Museum, TKM 530A, Budapest, 1996

[3] MFAV múzeum (Underground Railway Museum); 1051 Budapest, Deák tér, HUNGARY

[4] Szeberényi Márton: A Millenniumi Földalatti Vasút vonala és annak története (The story of the first Budapest metro); http://digitus.itk.ppke.hu/~szema/FJFVV_von.html as it on 30/06/2015

[5] M1 metro in Budapest; www.budapest.org as it on 30/06/2015

[6] Dr. Kubinszky Mihály - Lovász István - Villányi György: Old Hungarian trams; Budapesti Városvédő Egylet, Bp., 1978, ISBN: 9789637537112

[7] Line 1 (Budapest Metro); https://en.wikipedia.org/wiki/Line_1_(Budapest_Metro) as it on 30/06/2015

[8] Varga Ákos: A MillFAV múzeum, valamint néhány életkép – "Nyitott kapuk napja" (blog of professional), 2003. szeptember 20.; http://hampage.hu/trams/fav4/index.html as it on 30/06/2015

[9] The Milleneum Subway Line of Budapest by Varga Ákos Endre; http://hampage.hu/kozlekedes/fav4/e_index.html as it on 30/06/2015

[10] History of Budapest Metros; www.metros.hu as it on 30/06/2015

[11] Legát Tibor - Dr. Zsigmond Gábor: A villamos aranykora 1887 – 1923 (The golden age of the tram 1887-1923); Jószöveg Műhely; Budapest, 2012

[12] The Budapest Metro Network Line M1; http://www.uvaterv.hu/en/en/en/?mod=reference&cla=reference&fun=access&met=showProject&id=191 as it on 30/06/2015

[13] Varga Ákos – Szigeti Dániel: Ganz csuklós földalatti vasúti jármű (Ganz articulated underground train); http://villamosok.hu/metro/jarmu/fav/fav.html as it on 30/06/2015

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