The LNC Company Electrical System from the Twentieth Century into the Bethlehem Mines era

Foreword

The electrical system of the Lehigh Navigation Coal Company (LNC) was large, robust, had high horsepower loads and was served from a single point of contact which means the whole system has one incoming metering location. This single point of contact, unlike other mining companies with a number of electrical delivery points, was spread over a large area; resulting in complexity and required significant planning, design and operating support. This is a fascinating subject that gives a snapshot of the equipment and technology when viewed against present day practices. Little remains of the records, and moreover of any of the physical locations and equipment as well as people with direct knowledge of the system. There are a few us who were fortunate enough to have worked with electrician and engineers in the 1970's and those people were employed by the LNC when the company evolved from the steam era to the electrical era. Also in the 1970s, some of the electrical physical plant was still in place from the 1930s. In this article I tried to capture the details of the electrical system design and make up, to give an understanding of the system. I relied on photos, articles, drawings and the recollection and experience of those who had the opportunity to have known the people who "grew up" with the system many years ago.

In preparing this report/article I have taken a technical subject and explain much of it in layman's terms and where I used technical terms I included the definitions. However; in order to not lose the details, I tried to be specific and used engineering jargon so that for the technical reader they may see the extent and breadth of the LNC electrical system and how it has evolved over the years.
J F Stone

Introduction

The LNC during its heyday had one of the largest and substantial electrical systems in eastern Pennsylvania. Not only did the company have large heavy loads but it essentially was serviced from a single aggregate location or service whose overhead power lines crisscrossed the whole of the Panther Valley from Tamaqua to Nesquehoning.
The coal company's main incoming station was the Hauto Navigation Substation located due south of the Hauto Power Plant which was owned by PP&L in the latter years but built by the Lehigh Coal and Navigation Company. The power plant was located on Route 54 in the Hauto Valley of Pennsylvania. This power plant was of course, coal fired with anthracite coal as the fuel source.

The Hauto Navigation Substation essentially had circuit breakers for protection of the incoming source lines and for each of the outgoing or load lines serving the various collieries. The nominal voltage was 11,000 volts or 11 kV which was the voltage used as the distribution voltage throughout the valley. (This station is not technically a substation but a switching station since a substation has voltage transformation stepping down to another voltage and this station did not have voltage transformation (transformers). 11kV was the distribution voltage used by the coal company throughout the "valley" for its operations. (The term valley is often used collectively for the whole of the coal company property mostly in the Panther Valley)

The generation of the electric energy at the Hauto Power Plant at least for the industrial loads, was generating at an alternating frequency of 25 Hertz (Hz) or 25 cycles.
(The cycles refer to the frequency at which the power is generated. Most USA utility generation is at 60 cycles. In the past, some industrial loads were powered at 25 cycles. Amtrak and some other entities still utilize the 25 cycle frequency.)

At the peak of its existence, the overhead electrical system stretched from the Hauto Valley, to the Nesquehoning Colliery, to Black Rock Fan House, to the Summit Hill Strippings, to the fan houses on Sharp Mountain, to the Number 14 Colliery and looped back toward Coaldale and back over the mountain to the Hauto Valley.

The LNC electrical system served five collieries and supported facilities from this single point of service. At the peak production time the maximum load on the system was near 40 MW or 40,000 KW demand which is around a load of about 40,000 HP (horsepower).[1]

In the early part of the Panther Valley electrification, as the valley transformed from steam power to electric, some small local generators were in service. "The first venture of the Lehigh Navigation Coal Company into the power business was in 1905 when a power station was constructed at Lansford, Pa. The generating equipment installed in this station in addition to direct current generators used in furnishing power to a local trolley system and the quarter phase alternators used to supply the surrounding towns with power for lighting, etc it consisted of one 700 KVA, 2300 volt, 25 cycle, 3 phase unit and one 400 KVA, 2300 volt, 25 cycle, 3 phase unit." [2]

"In 1912 the (coal) company started construction of the Hauto Power Station and placed it in commercial operation in 1914. The station initial capacity at this time consisted of three 10,000 KW, 25 cycle, 11,000 volt turbo alternators and the plant quickly picked up additional customers to include the cement mills in the Lehigh Valley and the Bethlehem Steel Plant." [3]

This set the stage for the coal company to become a major producer as well as a consumer of electric energy. In 1917 the coal company sold shares of the stock of the power plant which eventually became Pennsylvania Power and Light Company (PP&L). Two interesting points to enumerate is that at the time there was a power factor or reactive clause in the power contract and the demand interval was based on an hourly period rather than a fifteen minute interval. (The demand is the integrated or average power in KW over a period of time. Today most utilities base the demand charge on a fifteen minute interval but the contract with the LNC was based on a one hour interval. Industrial customers are billed on the power they consume in KW H but they are also charged a demand charge or KW charge which allows utilities to recoup their investment for the capital equipment that is required to be available to serve the load)

In industrial facility locations most of the serving utilities have a power factor clause on their rate structure with the exception of PP&L but it seems that in the early days PP&L had a power factor clause. It is not known if this was specific to the contract with the coal company or if it was universal in the PP&L tariff. The purpose of the power factor or reactive clause is because of heavy motor loads which essentially targets industrial loads. This means that due mostly to intense motor loads, which not only draw real power or power that does work, they draw reactive power due to the motor windings and the iron core. This reactive power that is required by the loads causes an additional voltage drop and loading on the utility and plant facility system, and if the industrial facility does not address it, the utility needs to account for this and apply corrective measures. As a result, the utility imposes a penalty or incentive for the industrial customers on their electrical bill to remediate it. It is noted that the LNC utilized many synchronous motors at the mines to correct not only for the power factor penalty but also to compensate for the resulting voltage drop on their system. Moreover, the company had other facilities at nearby Alliance and Cranberry Collieries that used capacitors for power factor improvement as follows:

"A 660 KVA capacitor at Alliance Colliery and a 600 KVA capacitor at Cranbury Colliery paid for itself due to the power factor penalty in less than two years. [4] At the Lansford Colliery two 650 HP compressors were used with one idling as a synchronous condenser was used for this purpose." [5]

The electric power usage by the coal company was rapid and by about 1930 the company had "17 miles of two circuit transmission lines and 23 miles of one circuit transmission lines"[6]

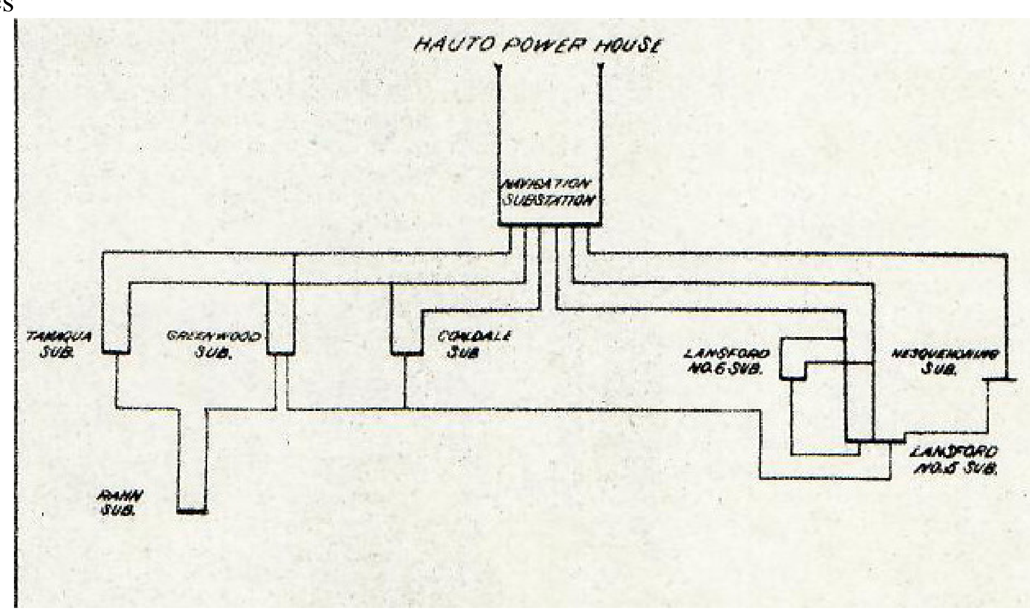


Figure 1 LNC 11,000 volt distribution system [7] (Single Line Diagram)

A single line diagram of the main feeders from the Hauto Navigation Station (coal company main station) to the major colliery loads is illustrated above. This shows a simplified routing of the power lines to the various colliery substations where the major loads existed. The voltage was generated at the Hauto Power Plant at 11kV and this power plant served other loads (customers) in addition to the coal company. This line diagram only shows the major colliery loads (locations) and does not shown any radial lines from the colliery substation to areas such as the mountain mine ventilation fans and other remote loads. Also, this single line does not show the various circuit breakers, transformers and loads but merely shows how the lines are routed. The specific substation single line diagram would show the detailed equipment at the substations.

The lines were named as Hauto – Tamaqua #1; Hauto – Tamaqua #2 etc. to differentiate the lines from each other. This convention is still used by some electric utilities today mostly, on their transmission system; PPL is one such company.

Substations and Major Electrical Equipment

The major substations were essentially located at the collieries and were substantial buildings usually constructed of brick or formed concrete. The substation building housed the 11 kV circuit breakers, the main step down three phase transformers (11kV/2.3 kV), the lower voltage circuit breakers and the major loads such as the supply for the mine hoists, the DC supply for the underground haulage and the main compressor mine air supply used for drilling inside the mines.

The main overhead bare line conductors were typically 4/0 stranded copper conductors which at 11 kV has a large load rating that can serve somewhere of around 9,000 HP. The lines were supported as typically on steel towers or poles and terminated onto the substation outdoor steel structure. The incoming and outgoing substation terminations included a set of station class surge arrestors (lightning arrestors) and a set of choke coils (The choke coils were a coiled air core reactor to minimize the probability of lightning surges traveling into the building equipment and damaging equipment due to the lightning surges. They provide high impedance to a lightning surge.) The 11 kV entered the building via porcelain feed-thru insulators through the wall and into the building. A practice that is obsolete and very uncommon today. (An example of this type of feed into a substation building that can be seen today is at the old PP&L Tamaqua Substation building across from Rotett Motors.) The 11 kV circuits inside the building consisted of open bus work supported on porcelain insulators at a safe height above the floor grade. This type of design was common in that era with open bus work for the 11kV and not used today.

The substations had one or more main step down transformers or transformer banks for the major loads which were powered at 2300 volts (2.3 kV). The transformers were oil filled and were suitable for outdoor use but a number of them were placed inside the substation building. This was much different than present day design where oil filled transformers are not allowed by code to be installed inside buildings.

In the major substations, the 11 kV utilized circuit breakers for the incoming feeders, the outgoing feeders, and the main transformer protection. Since the newest of the circuit breakers were installed before 1950, the circuit breakers for all 11 kV and 2.3 kV were oil circuit breakers (OCB). (Present day technology no longer uses oil circuit breakers and has not been applied inside buildings for many years) The typical substation design for the LNC included one main transformer bank which stepped down the voltage to 2.3 kV three phase. The design consisted of three single phase oil filled transformers banked together into a three phase bank (Present day practice is to use a single three phase transformer and oil filled transformers are not applied inside buildings)

These main transformers would serve as the source distribution to major loads such as the hoists and nearby ventilating fans since they were large motors which would require the higher voltage. The 2.3 KV would be routed inside the substation building to oil circuit breakers and then routed outside on overhead conductor runs to the mine hoists (engine house) and nearby mind ventilation fans. The air compressors in the substation building and the underground mine de-watering pumps, due to their size were 2.3kV motors as well. Where 440 volt (present day 480 volts) low voltage was needed for other equipment, other step down transformers were used for this purpose. The 2.3 kV and 440 volt systems were virtually all ungrounded systems and the transformer connections were delta/delta which was typical for electrical facilities in that era. This practice was carried over by the successor companies and followed along in anthracite mining companies, in general. Many other industries used the ungrounded delta systems such as large pipeline facilities. Present day industrial practices have moved away from ungrounded systems except for specialized applications and older installation; and when used, should have indication of a ground on the system or better yet, if the facility has good engineering support, utilize high resistance grounding.

Interior of the #10 Substation looking at the South wall [8]
The 11 kV circuit breakers are in the background; note the bus work
The main 11kV/2.3 kV transformers are on the left
The 2.3 kV circuit breakers are on the east wall left in photo and exit the east (wall) side
The rotary converter in the foreground supplies the DC for underground haulage

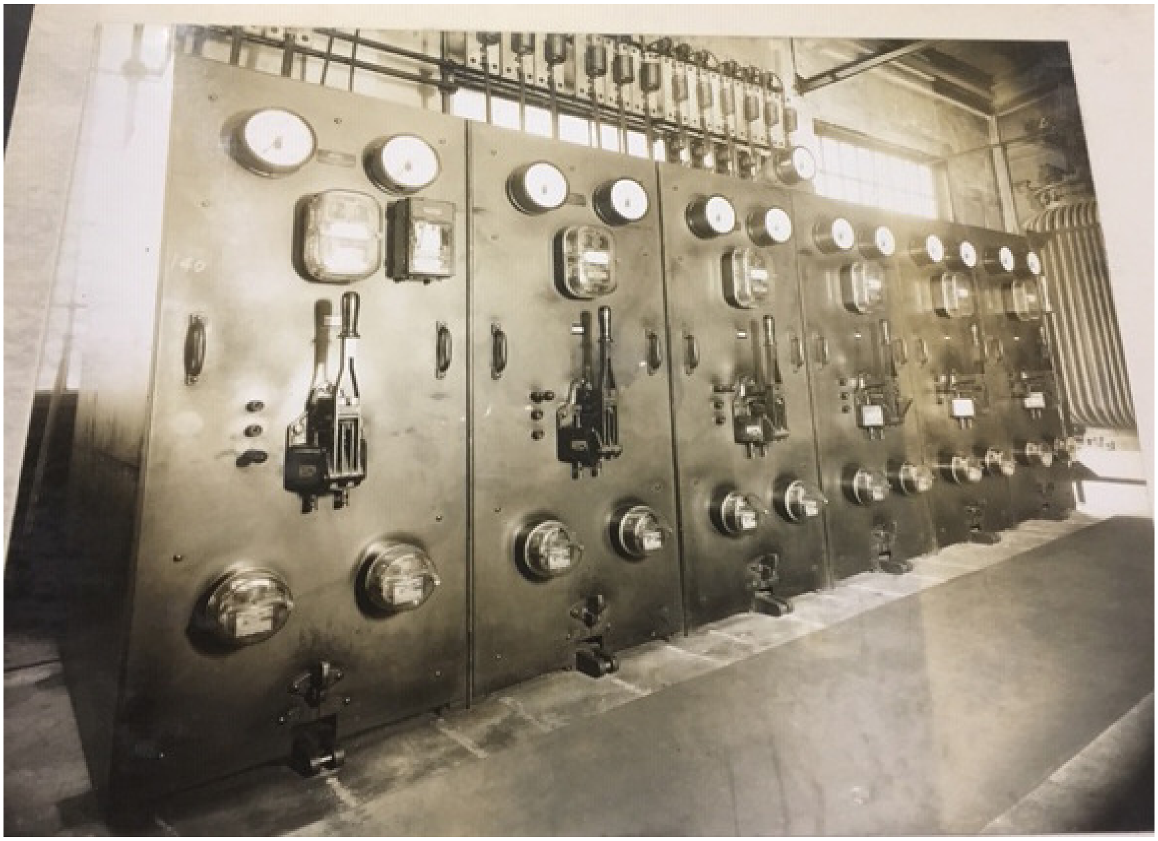


Figure 4 View of the 2.3 kV circuit breakers on the East wall at #10 Substation [9]
The circuit breakers are of a draw out constriction
Note the reactors (choke coils) on the feeders above the circuit breakers

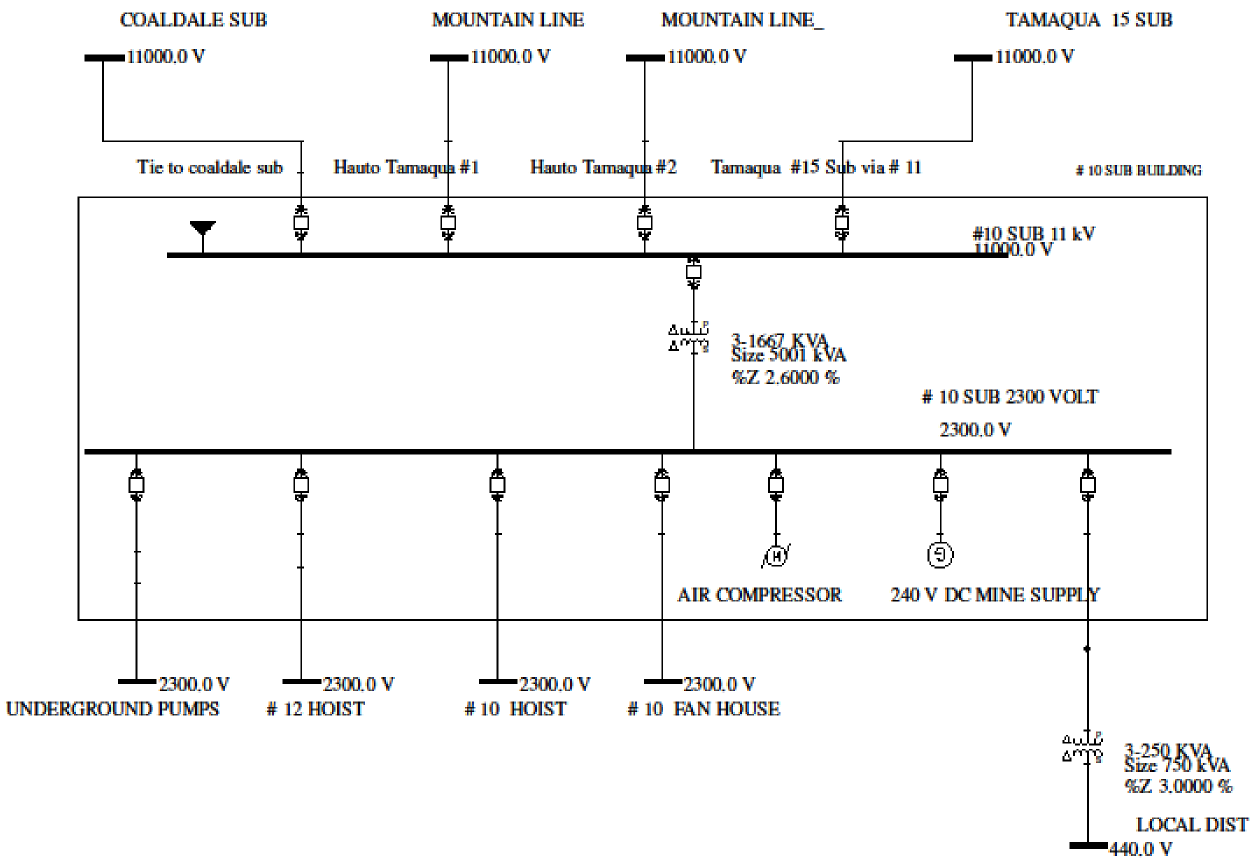


Figure 2 Single Line Diagram of the #10 substation typical design
This matches the 11 kV distribution and the photos

As noted, in that era, it was common to use one large step down transformer bank and feed the circuits at a lower voltage some distance, mostly on wooden poles, to the loads. The practice is also noted in the coal breakers of that era where less motors were used but the motors were of a larger HP and belt driven to several machines. Present day design usually is such that more, and often smaller, transformer and motors are used and placed closer to the individual loads.

One example of this practice is the motors at the #6 Breaker in Lansford which was built in the early 1920s. The Breaker alone had 20 motors in total but a total of 2,975 HP [10.] A similar type of plant in today's world with the same horsepower requirement would have many more motors with a smaller average HP level. Clearly, this is indicative that in present day practice, motors and motor control circuits as well as transformers are less expensive than their first generation counter parts.

The Hauto Navigation Station used oil circuit breakers as the distribution circuit interrupting device. Oil, actually refined transformer type mineral oil, is a very good insulator. The main contacts in an oil circuit breaker provide the opening, closing and the interrupting of the electric arc energy arc in the enclosed oil container. The oil tanks can be of a single tank design or for the larger units or three individual tanks. The oil circuit breakers at Hauto Navigation Station consisted of three large individual oil tanks, each tank being a single phase unit ganged together for three phase operation. The protective relays and the controls were mounted on a slate panel on the front with the circuit breaker behind the slate panel. A unique feature of the circuit breakers at the Hauto Navigation Station was that the circuit breakers were mounted on a roll out truck so that the circuit breakers could be disconnected from their circuits and moved out or disconnected from the source and load (or line side and load side) as a visible disconnect from the live circuit. (This design is a pre cursor of the modern draw out circuit breaker as used in typical ANSI Metal Clad Switchgear)

A pit existed in the floor where the oil tanks of the circuit breakers could be lowered to access the contacts of the circuit breakers. The contacts of oil circuit breakers require service and the oil required periodic testing and maintenance as well.

It was more common in that day for indoor applications to use stationary circuit breakers for the higher voltage rather than the evolving draw out or rack out circuit breakers. Oil circuit breakers have now been supplanted by air magnetic, vacuum and gas insulated circuit breakers for the arc interrupting means.

The Hauto Navigation Station because of its importance was a manned station twenty four hours a day seven days a week. It served as the source of electric power to the operation and as the single line shows provided multiple paths to switch among the various lines so that each colliery could be fed from multiple sources.

Exterior of the Hauto Navigation Substation looking south [11]
The two incoming overhead feeders from the Hauto Power Plant are on either end
The Hauto Power Plant would be to the north of this building

Interior of the Hauto Navigation Substation [12]
The circuit breakers are on the north wall facing the Hauto Power Plant
The two incoming feeders are on the ends corresponding to the11 kV single line

Hauto Navigation Substation Draw out Circuit Breaker “Truck” [13]
There are three individual circuit breaker oil tanks in which the arc is interrupted
Only the first is visible because of the angle of the photo

One of the newer company substations was the upgraded Coaldale Substation which was rebuilt in 1945. The 11 kV indoor circuit breakers were “Metal-Clad Switchgear using circuit-breakers of adequate interrupting capacity to meet the needs of the Pennsylvania Power & Light Company system as part of the new installation**.”** [14] Note the term *Metal-clad Switchgear* which is in common use today; meaning a circuit breaker assembly using draw out circuit breakers where the circuit breaker is isolated from the source and load when disconnected. These circuit breakers at the new substation were cable/conduit fed via a “pothead” from the outside open bus steel structure into the building, as opposed to bringing in the bare conductors thru porcelain insulator thru the wall. Therefore; no medium voltage (11 kV) open bus work was in the building minimizing that safety issue. This was a big improvement in the safe construction of the electrical facilities. Also, the article notes that the fault current supplied by PP&L had increased over-dutying the existing 11 kV circuit breakers at the station necessitating their replacement.

This first generation of the metal-clad switchgear still used oil circuit breakers at the time. This type of equipment was common in major industrial and petrochemical facilities. This equipment at this station was in service at the station although only to switch the incoming and outgoing circuits well into the 1980s.

Part of the reason for the modernization of this substation was for the installation of a replacement hoist on the number 7 shaft. The hoist was rated at 1750 HP and reported as the “industries most powerful hoist” [15]
The remainder of the mine hoists at the LNC collieries ranged between 1000 and 1250 HP. [16]

All mine hoists require variable speed and since precise speed is not needed and DC machines for this size would be prohibitively expensive, the wound rotor induction motor was the natural choice for this application. This was the type of motor used for the hoists from the time of conversion from steam power to the last hoist used by the company. It goes without saying that due to large horsepower, the motors were 2.3kV, three phase. One other item that is noteworthy in the Coaldale Substation modernization is that the DC used for mine haulage was produced using mercury arc rectifiers. The mine locomotives or mine motors required 240 volt DC either from onboard batteries and or from the single overhead centenary or trolley wire and the earth/track return. (In the early years rotary converters or DC-MG motor generator sets were used and were located mostly in the substation buildings. A borehole or alternately a route down the shaft was used to get the DC into the mine lower levels. The MG set was an AC motor directly coupled to a DC generator mounted on a common bed plate with the DC supplying the 240 volt output. The rotary is a fascinating and ingenious machine. It is similar to the MG set, but instead of having two machines it was one machine and somewhat combined using the same windings to achieve the same results. An important point is that the rotary converter is not electrically isolated while the MG set is isolated. The rotary converter can also be of a design where one frequency is used as the input and the output is of a different frequency as mentioned later in this article. Both the MG set and the rotary converters are bidirectional and are usually a synchronous machine although the MG set could be of a squirrel cage induction motor design. Clearly, since there is a relationship between the number of poles, synchronous speed and the frequency of an AC machine, and the frequency conversion is fixed it required a defined speed and pole number for frequency conversion.)

As noted the rotary converters used by the coal company converted the AC voltage to DC for the mine haulage service and were commonly 300 HP with the largest being 500 KW. [17]

This installation of the mercury arc rectifier, in this case for the DC mine power, had a captive three winding transformer with phase shifted secondary windings for harmonic control and to minimize the ripple of the rectified AC. The mercury arc rectifier is essentially a diode and the precursor of the solid state diode rectifier. This scheme provide a twelve pulse output waveform essentially the same as present day sources for large VFDs. (variable frequency drives) In stating the obvious, the issue of an AC rectified ripple was not as much an issue for DC MG sets and rotary converters as opposed to rectifiers that do have a high ripple. This transformer serving the rectifier was in this substation into the 1980s although long abandoned.

With evolution of the electric industrial technology, the mercury arc rectifier became the choice of the method to supply DC when needed in the late 1930s and early 1940s. This greatly reduced the amount of maintenance and complexity needed as opposed to a rotary converter. Rotary converts are still in use in a number of applications although mostly used as frequency changers such as from 60 to 25 cycles.

The fan houses used for mine ventilation were sometimes close to the main shaft areas, but many were located at remote areas. Since some of the fans could be well over 350 HP, the voltage of the fan motor was 2.3 kV. The motors were mostly squirrel cage induction motors and started on reduced voltage likely due to the large fan inertial loads or the motor windings not being braced for across the line starting. For remote locations an 11kV feeder from its nearby power lines to the remote site was installed and a step down transformer served the fan. The fan house had a building to house the motor and motor controls but the transformers were located outside on a pad adjacent to the building. As early as 1930, the fans were being operated as remote unmanned sites, a big departure from the days or steam or earlier electrification. Since the fan shafts were routes to the underground facilities they could also be used as convenient route for a remote source of DC to help improve the voltage drop on the DC haulage feeders. Arlington Fan House at the Tamaqua #14 Colliery had mercury arc rectifies to serve the remote south workings of the colliery. Other locations may have had the mercury arc rectifier as well as the rotating DC converter equipment was being replaced. But since money became tight into the late 1940s for the coal company it probably wasn't a priority to upgrade the rotary converters if the original equipment was not failing.

The air compressors were mostly located at the substation and the compressed air for drilling operations was transmitted to the mine workings by a borehole or down the shafts. A large air storage tank was often adjacent to the substation buildings. The motors were mostly synchronous, low speed, serving a piston type pump. The motors ranged in horsepower between 50 to 650 HP.

Significant pumping was needed for underground mining and the LNC had motors of several hundred horsepower at the pump stations located on the various levels dewatering the mines. One example of this was the fifth level pump house at the #10 Colliery which had three 650 HP motors. The cable that fed this pump house was a 2.3 kV cable, 800 foot long and installed in the #12 shaft. This cable was three phase, 800 MCM stranded

copper and similar to an interlocked armor type cable. The cable weighted an incredible 16,544 pounds and was supported on the top of the shaft by one single support. At the time this cable was the largest cable used in a coal mine in the USA. [18]
Cables of this type were typical and to this day some of these cables are visible in at least one of the remaining shafts.

The Later Years
After the LNC stopped mining operation in the valley in 1954, Pierce Mining started the Coaldale Mining Company which operated the #8 Colliery and the #9 Mine. About the same time, The Panther Valley Coal Company was established and re started the Lansford #6 Colliery and the Nesquehoning Mines. These two operations were about all that was left of the extensive coal company facilities. In late 1957, the #6 Colliery and the Nesquehoning Mines were acquired by the Coaldale Mining Company and shortly thereafter, they were shutdown.

Around the late 1950's or early 1960s Fauzio Brothers started the Greenwood Mining Company or the Greenwood Stripping Corp. and purchased or leased a portion of the LNC properties when Coaldale Mining Company ceased all operations. This ended deep mining in the valley until a small group of miners leased the #9 Mine and operated the water level tunnel as Lanscoal Coal Company.

Greenwood Mining constructed a new coal breaker at the site of the old # 14 Breaker and it was noted that much of the machinery from the old shuttered #8 Breaker was used at the new plant. Moreover, there was a good deal of old electrical equipment available at the mining operations and was promptly put in service for use in the new company operations as needed. The new company used strip mining exclusively so essentially the support electrical facilities for underground mining became unnecessary.

The new coal breaker had many more and smaller motors located at the individual machinery as opposed to the old #6 and the number #8 Breakers. The utilization voltage at the plant was 440 volts. Two outdoor transformer banks were located near the plant and the 440 volt lines were routed overhead to the indoor circuit breakers inside the plant as the utilization voltage. Each transformer bank consisted of three 500 KVA transformers with a high side relayed OCB (oil circuit breaker) and no low side protective device. The transformer connections were the typical delta/delta consistent with the commonly used convention.

Therefore, at this time the 11 kV distributions to the #6 Collieries and Nesquehoning operations were abandoned. The tie line from Number 5 substation to Coaldale was removed; the Coaldale Substation and the Number 10 (Greenwood) had no need of 2.3kV utilization and merely became a switching station. The Tamaqua #15 Substation was bypassed since it no longer served a purpose. The only lines that remained in service were the Tamaqua and Coaldale lines and the tie line from Coaldale to Tamaqua routed via the # 11 area (Rahn).

Shortly thereafter the coal company advanced the Job 111 stripping operation which extended the mining pit toward the Number 10 area and power lines from the north mountain to Number 10 Substation were removed. This left the #10 substation with only feeders from the #14Tamaqua to the #8 Coaldale tie line.

One can view a portion of the original Coaldale #11 (Rahn) power line which runs on wooden poles on the north side of Rt. 209 in Seek and then along the railroad toward Coaldale. The line is distinguished by the triangular framing of the phase conductors different than the typical flat cross arm design of local utility practice. Also the line is characterized by poles that have been in service for ages. One can also note that the poles only carry three phase conductors and no neutral; different from typical utility practice today for multi grounded wye systems. Another example of the company distribution visible today are the old abandoned red towers in place near the old Bagging Plant in Lansford, the towers of which, were used to feed the # 6 and # 5 substation as shown on the single line diagram.

The coal company at this time used electric power shovels, diesel electric blast-hole drills and diesel draglines. The electric power shovels originally in use by the LNC had 2.3 kV main motors. The supply used a flexible portable cable rated for the voltage and current from a substation to the machine. In those days, and in the early days of Greenwood Mining Company, 2.3 kV and the ungrounded system was acceptable for the source of power to the electric power shovels. At some point in time around the 1960s with the evolution of the mine laws and more stringent electrical requirement by MSHA (Mine Safety and Health Administration) required a ground wire in the 2.3 kV portable feeder cable to the machine. Additionally, resistance grounding was required. This naturally translated to a transformer with a secondary or low side neutral connection and a 4,160 volt (4.16 kV) system and or higher voltage for larger machines. Many medium voltage motors are reconnecable and dual rated for operation on a 4 kV and 2.3 kV systems.

In this period, the state of Penna. was concerned about flooding of some areas because underground pumping stopped and water in the mine pools in the valley was rising. As a result, the state installed two deep well pumps at each of the #10 coal shaft and the #14 water shaft. The pumps were rated at 800 or 1,000 HP. (The deep well pumps were centrifugal turbine pumps where the pump bowls were located several hundred feet below the surface with the motor mounted on the surface at the shaft collar. This hollow shaft design motor supported the weight of the shaft with a Kingsbury thrust bearing on the top of the motor. The motor/pump extension shaft was installed inside the water column line which extended down to the pump bowls). The water discharged on the surface into the Panther Creek.

Since the state was purchasing the equipment, and around this time it was becoming commonplace to use a single three phase transformer rather than three single phase transformers, the new transformers were purchased as three phase units, different from the historical LNC trend. Power factor correcting capacitors were installed in the 4 kV motor across the line starter package.

This pumping allowed Greenwood Mining to mine deeper around the #10 area in that section of the mine pool in the valley between the # 9 areas to the #14 area which worked out well for the coal company.

Sometime around the mid-1960s, PP&L decided to close the Hauto Power Plant which was the source of the 25 cycle power not only for the mining operation but also for a part of the Bethlehem Steel Plant in Bethlehem Pa. The end users of the 25 cycle power were given a choice to either be paid to convert their facilities to 60 cycles or to allow PP&L to install rotary converters, to allow their facilities to continue to power the sites at 25 cycles. Bethlehem Steel chose the latter and Greenwood Mining chose the former. (The last rotary converter used at Bethlehem Steel was located at the Converter Substation on the north side of the Minsi Trail Bridge in Bethlehem. It was rated at 25,000 HP.)

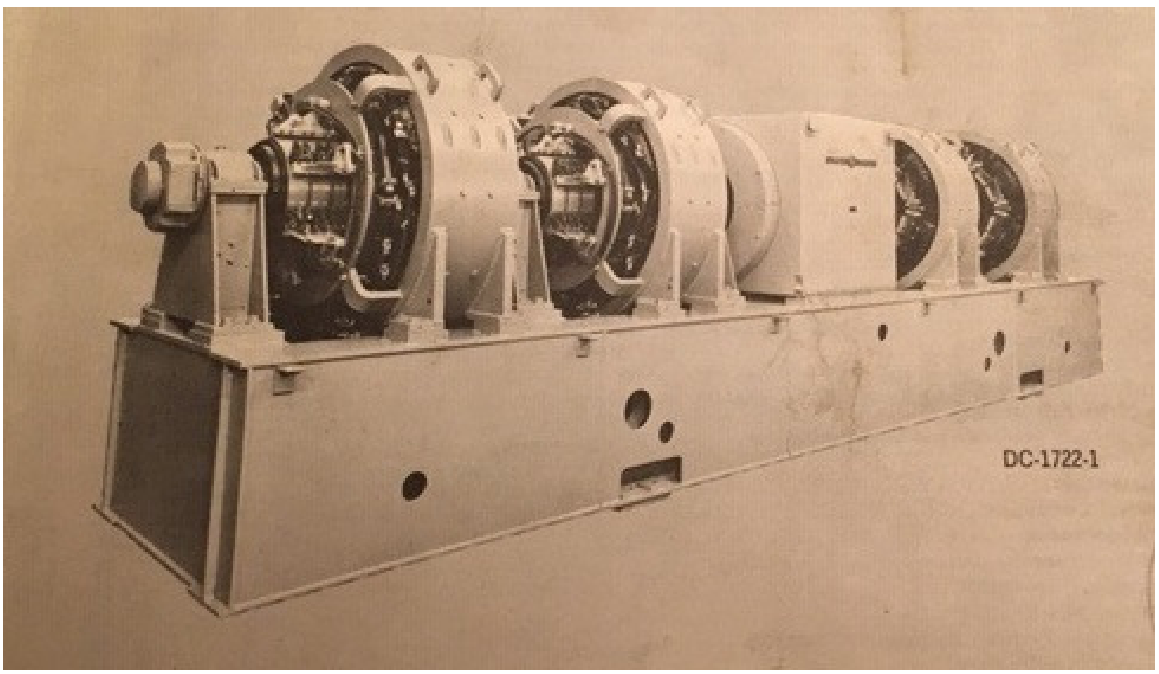
In the case of Greenwood Mining, some clever fellows figured they can pocket the PP&L money and save by converting the motors to 60 cycles and keep the existing transformers and use them on 60 cycles. (Many of the motors at the #14 breaker were old and for a given HP the older motors were physically much larger than present day motors for the same HP than the 25 cycle motors. In discussion with some of the electrical personnel who were present during the conversion, they noted that 25 cycle motor had more iron and less copper than the 60 cycle motors. These motors were re-wound because with a squirrel cage induction motor the speed depends on the frequency, so smart engineering was needed at the Westinghouse and General Electric shops where they were converted to 60 cycle service. In the case of transformers, the impedance of a transformer is directly related to the frequency, so 25 cycle designed transformers operated at 60 cycles, have a much higher impedance so this needs to taken into account in the application. These transformers were physical large and well overdesigned than their present day counterparts and could be significantly overloaded. Moreover, they were moderately loaded and voltage issues were not a significant concern.

By this time, the PP&L nominal voltage was evolving and the nominal system voltage was now 12,470 volts (12.47 kV) which is a common nominal voltage for many utilities, while the nominal nameplated transformer voltage was 11.5 kV. (Fixed no load voltage taps were present on these transformers) All of this led to a very challenging project, while trying to keep the operations going which is a tribute to the group developing the conversion plan at the time.)

During the course of the Greenwood Mining days, the company added a fine coal plant near the site of the former #12 Colliery and the new plant was called the #12 Breaker which was located south of Coaldale. (Although it was technically not a breaker but a fine coal plant since it didn't have a head house for the larger sizes, but not many will argue the point at this stage of the valley history). Also, a new Bucyrus 480W Dragline was purchased to operate at the Little Italy Strippings (Nesquehoning Wash Shanty Area). This machine had an MG set (motor generator) with a 1,000 HP, synchronous motor while most of the older original shovels in the operation, had squirrel cage induction motors. In order to power this machine, since nearby LNC high voltage facilities were long abandoned, a new 69 kV service from PP&L was installed near the WLSH radio station which is between Lansford and Nesquehoning.

In this era for example, the various motions on a shovel or dragline such as the hoist, swing, drag and crowd utilized DC motors because speed control was needed. The DC motors are directly connected or wired to the respective DC generators with no switching device in the armature circuit. The DC generators were mounted on a frame or bedplate with all the generators driven by a common shaft from the MG set main AC motor which could be either an induction or synchronous motor. (The blast hole drills at Greenwood Stripping used to drill the rock in which charges were placed to blast the rock, operated the same except that the prime mover was a diesel engine. At other locations, the blast hole drills could have an AC motor as the prime mover on an MG set.)

As noted the DC motors on the machines were directly connected to the respective DC generators with no switching device in the armature circuit. This type of control is known as the Ward Leonard Control and it was universal in many industrial applications in that period.



Typical MG set for shovels or Draglines [19]
The DC generators are shown driven by the main AC motor
For perspective the bedplate is about 20 feet long

The DC generators and motors for this type of application are compound wound machines with shunt fields, series fields and commutating coils. The generator is differential compound wound which means that the series field act to buck the main shunt filed, thus the term differential compound. In essence speed control is achieved by powering the DC generator and changing the excitation on the DC generator shunt field in intensity and in polarity to control speed and direction i.e. swing left/right; hoist/lower. The generators have two shunt fields such as one in the forward or hoist and one in the reverse or lower and they act in tandem. By varying the input to the generator field from a main controller, the speed of motor was controlled.

The second generation evolution of the control in a Ward Leonard system was in the use of the rotating control. General Electric developed a machine called an Amplidyne and Westinghouse's model was called a Rototrol. These are small DC generators with a number of shunt wound control fields. The machines are sometimes called amplifiers because each of the control field are used for various control functions such as the main input, the current (torque) feedback, the voltage (speed) feedback, the stabilizing field etc. Some of the fields serve as boosting the output and some of the fields serve as bucking (reducing). The net arithmetic sum of the control field excitation produces a generator output proportional to the control field excitation. This is why the term amplifier is sometimes used.

The next generation of the control system was the magnetic amplifiers or "mag amps" and then onto the solid state device known as Amplistats which are a variation of the mag amp. The final control prior to digital control was the operational amplifier or "opamp" All of these controls are the same as used in other industries such as rolling mills, power plant generator control and other processes requiring speed or excitation control.

Since the world of power electronics had significantly evolved, present day technology uses AC motors for speed control applications on draglines and electric power shovels without an MG set; and motor speed control is achieved with a VFD.

So in the later years of Greenwood Mining when Bethlehem Mines purchased the coal lands in late 1974, the company had operating, the deep well pumps at #10 and #14, the Number #14 and the #12 Coal Breakers, a Bucyrus Erie 120B, 170B and a 190B electric shovel, a 480 W dragline, four diesel electric blast hole drills and two diesel draglines and various shops and offices. The areas being stripped at the time were the Little Italy (Nesquehoning) Job and the #10 area (Greenwood) Job 111.

The load continued to be served from the main company Hauto Navigation Station, but the load was only about 8,000 KW demand which is about 20% of what it was in the heyday of the LNC company peak operations. Also, the remaining overhead 12.47 kV distribution system consisted of the system to the #14 complex and the lines to the #10 area by way of the Coaldale #11 tie line to #14. Note that on the original single line 11 kV distribution, the main feeders to the #10 Substation from the Hauto -Tamaqua Lines were removed due to the interference of the job #111 strippings. Lanscoal #9 mine formerly on the LNC main electrical system was now a separate PP&L service during the Greenwood Mining days.

Conclusion

The electrical equipment used in the facilities described in this article are long gone and the design of heavy power usage has evolved and diverged from these early practices. The concept however; and the fundamental of the application of electric power remain the same. By considering the challenges that the previous generations of electrical personnel have overcome and successfully produced robust systems, should give the reader a historical perspective and inspire continued enthusiasm of this field of study.

Author

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