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Motor-Generator Sets for ac to dc Conversion

In his "History" article "The Rotary Era, Part 2" that appeared in the November/December 2013 issue of *IEEE Power & Energy Magazine* (vol. 11, no. 6, pp. 96–105), Tom Blalock stated that the reason that Bethlehem Steel chose to use motor-generator sets in certain locations rather than rotary converters was not known. I hope I am able to shed some light on that choice.

I worked in a portion of the Inland Steel Company's Indiana Harbor Works, a facility now known as the Acelor-Mittal Indiana Harbor Works–East. I worked in both the #2 blooming mill (constructed about 1916) and the #2A blooming mill (constructed about 1964). Both mills were two-high reversing rolling mills. The #2 bloomer was driven by a dual-armature dc motor, which in turn was powered by a motor-generator set that consisted of a single 6,000 hp, 25-Hz, 2,200-V induction motor, which was direct connected to two dc generators and a flywheel. This equipment (Westinghouse) was later upgraded to 7,000 hp by improving the temperature rating of the winding insulation. If my memory serves me right, the rated r/min of the induction motor was 300.

It was interesting to see a single installation that included both a "last hurrah" motor-generator installation and one of the first high-power electronic control systems side by side.

The mill stand driven by the dc motor would be placed under a very sudden and heavy load by the introduction of an ingot between the rolls and would then have the load drop off just as precipitously when the other end of the ingot dropped out after rolling. The rotation of the dc motor and mill stand was then quickly reversed (no mean trick since the double-winding armature alone weighed over 90 tons) and the rolling and reversing process repeated several times. From this description, plus noting the inclusion of a flywheel, it is evident that the added rotating mass of the separate motor and generators was not a liability but an asset and probably the primary motivation for using the separate electric machines.

The #2A bloomer, constructed roughly 50 years later, incorporated many of the same features, right down to the motor-generator set with double generators and a flywheel. The motor, of course, was now a 60-Hz machine, and improvements in the controls allowed for the use of separate 4,000 hp dc motors to individually drive the mill stand's two rolls. The #2A bloomer was a General Electric (GE) plant. This mill's load profile was very similar to #2's, and the two stands operated together, with the #2A mill further processing steel from #2 for certain products, until #2 was razed in 1991. To my knowledge, #2A bloomer remains in service today.

Interestingly, the 21-in mill, which rolls steel produced from #2A bloomer, was one of the first solid-state rolling mills. Installed at the same time as the #2A bloomer, it consisted of eight roll stands of 3,000 hp each. It was a GE system; Silcomatic is the brand name that comes to mind, but my recall may not be accurate. It was interesting to see a single installation that included both a "last hurrah" motor-generator installation and one of the first high-power electronic control systems side by side.

I hope that this helps.

—David E. Mertz

Author's Response

I greatly appreciate the comments from David Mertz regarding the use of flywheel motor-generator sets for rolling mills at Inland Steel and especially the simultaneous installation of such

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classical equipment and pioneering GE solid-state control equipment in 1964.

In fact, a very similar flywheel motor-generator set installation was used for a merchant blooming mill at the Bethlehem Steel plant in Pennsylvania. However, motor-generator sets were also used (rather than rotary converters) in some locations for the more mundane task of simply supplying 250-V dc power for general usage around the plant.

I was also interested in Mr. Mertz's comments regarding the rapid reversing ("plugging") of the rolling mill motors. Around 1970, while I was employed at the GE High Voltage Laboratory, I was sent to the then-new Bethlehem Steel plant in Burns Harbor, Indiana, to install a transient voltage recorder on the power system for a rolling mill. There had been some equipment failures that seemed to be the result of high-voltage surges.

> Suddenly, a thunderously loud sound occurred.

I was in a basement underneath the rolling mill, along with a Bethlehem engineer and an electrician, to install the transient recorder. Suddenly, a thunderously loud sound occurred, which was accompanied by an actual shaking of the building. I recovered from the shock of that event and asked my companions something along the lines of "What in the **** was that?" They chuckled at my nervousness and explained that it was nothing to worry about because "they just reversed the roll stand."

—Thomas J. Blalock

Price and Quality of Electricity After Deregulation

Electricity deregulation is supposed to bring price reductions to consumers. However, simple economic reasoning indicates that the price and profits will tend to increase and the quality of electricity will tend to decline after deregulation.

Let us first discuss how prices change in deregulated marketplaces.

There are plenty of substitutes for ordinary goods such as food or clothing. For example, if beef becomes too high priced, one may substitute pork or chicken for beef. However, there is virtually no substitute for electricity. Let us consider elevators. Any high-rise building is equipped with an emergency staircase. But such a staircase is not the substitute for an elevator. It is for emergency use, as one may realize by climbing about ten flights in a hurry. Now, elevators are useless without electricity. Consequently, electricity is almost the necessity of life for upper floor dwellers of high-rise apartment houses.

Refrigerators are similar. No one switches from electric to gas refrigerators when the price of electricity goes up by several percent. In addition, it is a time-consuming and expensive proposition to equip each household with a backup generator for running electric appliances and equipment whenever power line electricity is high priced. Consequently, when the price goes up by a certain percentage, the quantity demanded of electricity will not go down as much. In other words, the ratio, E_d, of the percentage decrease in demand to the percentage increase in price is less than one. For example, a 10% price increase may induce only a 5% decrease in quantity demanded. In this case, E_d is 5% divided by 10%, which is 0.5. Economists call E_d with a minus sign the price elasticity of demand.

> Simple economic reasoning indicates that the price and profits will tend to increase and the quality of electricity will tend to decline after deregulation.

If the price goes up 10% and the quantity goes down 5%, then the total revenue of suppliers goes up about 5%, since revenue is given by price times quantity. The increase in revenue and the cost reduction due to the decreased quantity are both additions to profits. Similarly, if E_d is less than one, profits increase with increasing price. So the suppliers will try to raise the price at every opportunity. When E_d is one, there is no increase in revenue but the cost reduction due to the decreased quantity is still an addition to profits. When E_d increases further and the revenue decreases more than the cost reduces due to the decreased quantity, profits start to decrease. Only then will the suppliers get enough incentives to reduce the price.

Now suppose that E_d is less than one, and the number of suppliers is more than one. If one supplier tries to increase his percentage share by reducing his price, other suppliers will match the price reduction to defend their positions. The outcome is no change in percentage shares, and the price is reduced. Since E_d is less than one, the total revenue decreases resulting in reduced profits. On the other hand, if no one tries to increase his percentage share and someone announces a good excuse to raise his price, then everybody else will follow and the price is increased. The total revenue increases, resulting in increased profits, and every supplier is better off. So, if E_d is less than one, the price of electricity and profits will tend to increase, regardless of the number of suppliers.

The reliability of electric supply will tend to decline and the frequency of black out will tend to increase after deregulation.

In most countries, people use electricity to maintain the level of everyday life. They are reluctant to lower the level, and the E_d is expected to be less than one. Using available data from 2006 to 2011, the E_d of Japanese consumers is calculated to be about 0.4.

The cost of generating electricity may go down after deregulation because the cost reduction becomes a profit. However, this will not benefit consumers, since the price is kept high, unless E_d becomes greater than one. The ratio E_d will be greater than one when

- ✔ a sufficient number of backup generators are distributed among consumers
- ✔ substitutes for electric appliances and equipment become ready for use by consumers
- ✔ people accept the life style of the Amish.

Next, let us consider the quality of electricity. After deregulation, different suppliers use the same power line. So the qualities of electricity supplied by different suppliers become identical. This means no competition for better quality. On the other hand, if regular maintenance and component replacements are postponed or minimized, the profits, now deregulated, will collectively increase. Furthermore, the responsibility to keep good quality is fragmented among several participants after deregulation. So, the reliability of electric supply will tend to decline and the frequency of black out will tend to increase after deregulation.

In conclusion, the price of electricity and the profits of suppliers will tend to increase, and the quality of power line electricity will tend to decline after deregulation.

—Kaneyuki Kurokawa, Life Fellow