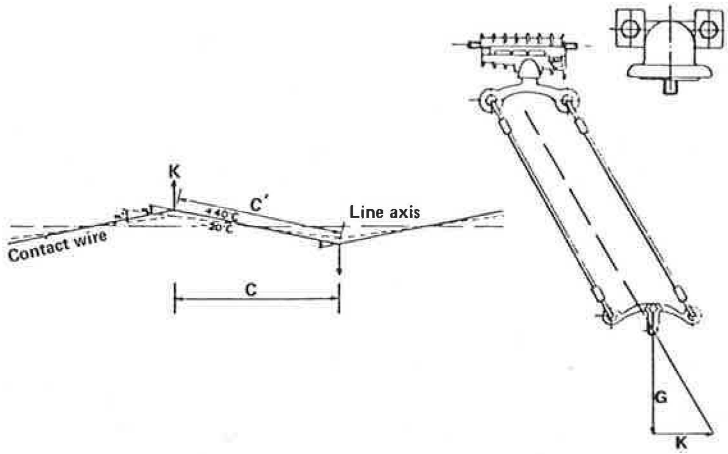


Figure 1. Suspension system that involves slanting pendulum.

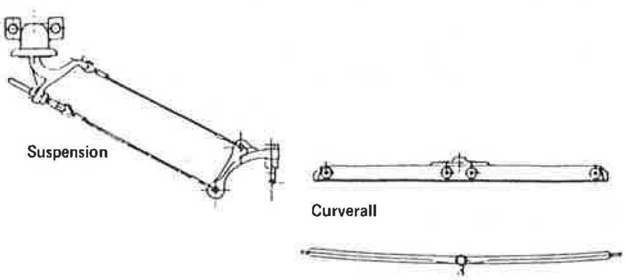


Figure 2. Parallelogram pendulum.

overhead contact lines has shown that dewirements are fewer with the elastic type than with the rigid type. On the straight angle and on curves, considerably greater speeds are possible with the elastic system. In view of the technical advantages of the elastic system, the life cycle of the sliding contact carbon is considerably longer. This cycle varies depending on supplier and time of the year, but sliding contact carbons have been known to last 2,500 miles or more.

# Supervisory Control Systems

Thomas E. Margo

The traction power substation is one of the vital elements in an electrified transit system because it must provide power in an efficient, safe, and reliable manner. These features are provided in the design of the power conversion equipment installed in the substation. However, a key element in any transit system operation is the ability to know what is going on and to effectively respond to that situation.

For traction power substations, this information and control function can be provided efficiently by a supervisory control system--generally referred to as a supervisory control and data acquisition (SCADA) system. A SCADA system provides three basic functions: (a) control (e.g., trip or close a circuit breaker or other controllable device), (b) indication (e.g., report of the status of a device or function), and (c) telemetry (e.g., reporting the quantitative measurement of an item such as voltage or current). With this capability, efficiency and flexibility in traction power substation operation can be achieved.

BACKGROUND

Almost all electrified transit systems have adopted the principle of automatic traction power substations. This includes the newer transit systems designed and constructed over the past several years as well as the older transit systems that date back to the early 1900s. An automatic substation can be defined as an unmanned substation in which the equipment is designed with automatic features (protective circuits, load-measuring circuits, etc.) that provide for safe operation of the substation in response to the demands of the electrified traction power system.

The Southeastern Pennsylvania Transportation Authority (SEPTA), the transit operator in Philadelphia and the surrounding counties, has had an ongoing program of renovating old traction power substations and adding new substations where system changes or expansion dictate. All such substations become automatic substations and SEPTA has adopted the policy that all automatic substations will incorporate supervisory control. The supervisory control system concept provides complete optional, overriding control of the automatic substations from a centralized location. The advantages offered by this centralized supervisory control system concept include economy of operation (because the substations are unmanned); continuous real-time update and display of electrical system status; prompt operation of equipment in response to dispatcher's commands; and greatly increased flexibility of operations in response to operational problems (accidents, electrical faults, etc.,. These items are all of vital importance to the transit system operators.

Many years ago, SEPTA had used electromechanical supervisory control systems at several substations. These were of the single-master, single-remote type; the master was installed in an existing manned substation and one other substation via the supervisory set. This afforded some economy of operation and provided some of the other advantages noted above.

To realize more fully the benefits and advantages of the substation supervisory control system, a centralized supervisory control facility was established at SEPTA's operation headquarters for all new substations that were added or existing ones that were modernized. It was decided at the time (about 1970) that the SCADA system to be used would be the one-on-one type with a master control unit and a corresponding remote terminal unit for each substation. Thus, each substation essentially had its own SCADA system that operated entirely independent of the other systems. The independent one-on-one SCADA system was chosen for reliability purposes, because all the substations being converted to supervisory control primarily served the rapid transit portion of SEPTA's electrified transit system.

Since 1970 SEPTA has installed an electronic one-on-one SCADA system for each substation added or modernized. SEPTA has had successful experience with this equipment and is satisfied with its operation. However, there are two major items that must be contended with--cost and technology. The one-on-one SCADA system is the most expensive way to provide supervisory control, especially if done in a piecemeal fashion. Also, electronic technology is making advances at such a pace that the electronic technology of the 1960s and the 1970s is practically obsolete. It is becoming increasingly difficult to obtain electronic components for 10-year-old equipment. Therefore it was necessary for SEPTA to reexamine its commitment to the one-on-one SCADA system.

## SCADA SYSTEMS

### Generic Types

In its investigation of the various systems available, SEPTA found that the systems could be grouped into two basic types: one-on-one, which has a master control unit and a remote control unit for each substation; and the single master, which provides one master control unit for all substations and a remote control unit in each substation. The latter type can also be configured in a dual-redundant scheme for enhanced reliability (see Figures 1-3). Furthermore, the single-master system can be broken down into two other categories: microprocessor-based master station and computer-based master station. Both categories are available in dual-redundant configurations.

It should be noted that many transit operators want the SCADA system to do more than just operate substations. Features such as system reports, cal-

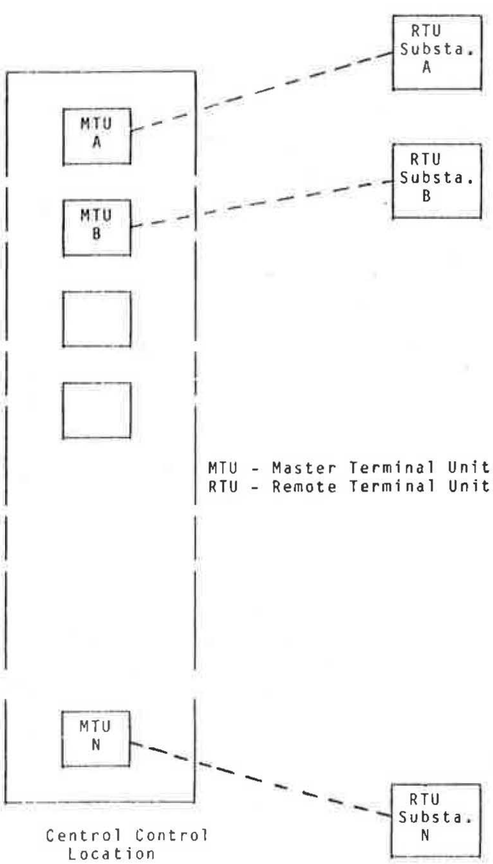


Figure 1. One-on-one SCADA system.

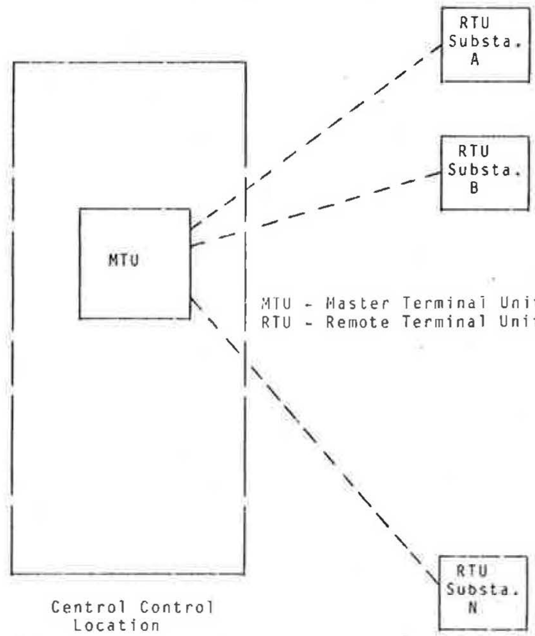


Figure 2. Single-master SCADA system.

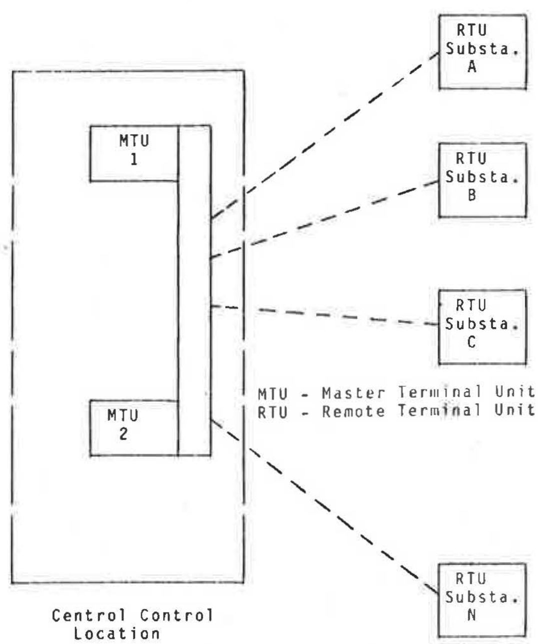


Figure 3. Single-master SCADA system, dual-redundant configuration.

culation capability, system data storage, data trending, passenger facilities supervision, and so forth, may be desired. Such requirements will likely result in the selection of the single master system and, depending on the size of the system to be operated, will usually result in the choice of a computer-based master station.

### Reliability

It is difficult to compare quantitatively the reliability of the one-on-one system to the single master type. The former is likely to be much better than the latter when viewed from an overall system basis. However, it is questionable whether the reliability of the one-on-one type is significantly greater than that of a single master type with dual-redundant configuration to warrant the greater expense of the one-on-one system. This evaluation is system specific and must consider many other facets of operation that the transit operator may wish to incorporate into the SCADA system.

### Cost

The transit system operator must always consider the costs, both operating and capital, associated with the purchase, installation, and operation of equipment. This is especially important in evaluating electronic equipment when the technology is constantly undergoing dramatic changes. The system purchased today may be obsolete 10 years from now.

General comparisons can be made of the costs associated with the three types of SCADA systems likely to be considered: one-on-one, single master (microprocessor based), and single master (computer based).

### Operational Features

Regardless of the system chosen, several key features that are highly recommended by SEPTA should be incorporated into the SCADA system design. These include an error-detecting code, a select/check-back operation, an audio and visual alarm indication, logging, a means to secure communications, and a man-machine interface. Other features that depend on operational and other specific system needs should also be given consideration.

### Support Considerations

In order to implement effectively a SCADA system, a number of items should be provided as part of the system's purchase. These include the following: system documentation, training, maintenance/warranty contract, spare parts, and test equipment. It is recommended that these areas be given close attention to ensure that the items are adequately defined and determined.

## CONCLUSION

To date SEPTA has had a positive experience with the operating one-on-one SCADA system. It will shortly put into operation a dual-redundant computer-based single-master type system. This new system will handle not only substation control but will also have the capability for single system supervision and fixed-facility supervision. SEPTA is convinced that the use of the SCADA concept has produced significant benefits in the operation of its transit system.

# Rebuilding Seattle's Trolley Overhead System

Stuart Maxin (presented by Robert Powell)

Seattle Metro has been responsible for public mass transportation in the metropolitan Seattle-King County area since January 1973. Before that time, public transportation was provided by several smaller organizations. One of these, the Seattle Transit System, had been operated by the city of Seattle. A part of that system was a trolley coach overhead network covering some 32 route-miles that were in operation when Metro took over. Thus, the overhead system inherited by Metro was old and in many areas had been worn to the limit of its service life.

On December 1, 1972, the city of Seattle and Metro signed an agreement (Transit Transfer Agreement), which described how Metro would take over the Seattle transit system. Metro would continue to operate the existing trolley system. The agreement also provided for a future expansion of the trolley system at the request of the city. A complete rehabilitation of the old 32-mile system was included in a transit improvement project outlined by Metro in early 1973. In 1974, at the request of the city, the transit improvement project was amended to include an expansion of the overhead system. How much expansion was to be effected was to be defined at a later date. But this lack of definition on specific routes and degree of expansion led to some of the problems that were encountered during the design phase.

During the planning phase, a number of decisions were made that later were to have significant impact on the design and during the construction stages. Even though a planning effort was made, a number of unforeseen problems were encountered during design and construction. Essentially these stemmed from the fact that this was the first major construction on a trolley bus overhead system in the United States in some 30 years, and experience was in extremely short supply. As a learning curve was established and overcome, the problems began to diminish.

Early in the planning phase, a detailed study of power distribution alternatives was undertaken by Metro staff. This study had to consider a city policy that required the eventual elimination of all overhead wiring except, of course, the trolley contact wires. The alternatives to be considered were thus reduced to (a) place the existing feeders underground; (b) place reduced-sized feeders underground and add small rectifier substations; or (c) construct a feederless system that uses small rectifier substations. After a comprehensive research and study effort, alternatives a and b were found to be much more expensive when compared with the feederless system due to the high cost of installing underground feeders. In recommending a feederless system, the study concluded that "to avoid the expense of feeder cables, it is necessary to eliminate them and let the trolley contact wires carry all the current required. To minimize voltage drop, the trolley contact wires need to have as high a conductance as can be practically attained and the current handled by each feeder circuit needs to be reduced. This requires that distances between power feed points to the trolley contact wire system be made small."

To obtain a maximum conductivity in the outlying areas, it was decided to use 4/0 hard-drawn copper