MOTT MACDONALD

CTA WESS Summary Report

A study on how implementing a Wayside Energy Storage System will impact the CTA Red Line

April 28, 2017

Public Version

Prepared for the Regional Transportation Authority (RTA) and the Chicago Transit Authority (CTA)

Mott MacDonald
10 South LaSalle Street
Suite 2520
Chicago IL 60603
United States of America

T +1 (312) 894 5369

mottmac.com/americas

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Contents

Executive summary

Based on the results of the Load Flow Analysis and the site surveys, the preferred option would be to install one 2000 A (approx. 1.5 MW), 6 kWh to 8 kWh Wayside Energy Storage System (WESS) at 79th TPSS on the CTA Red Line.

However, the cost to install and commission this WESS would be between $600k and $700k and the energy savings would be around $25k per year. This gives a payback period of around 25 years. The payback period is on the high side not only due to the inherent high receptivity of the CTA system, but also due to the low cost of energy CTA already pays at 7 cents per kWh.

The price of WESS is decreasing as they are becoming more “mainstream” (the price of super capacitors is decreasing year on year) so if the cost of the WESS decreased by 10 % and the cost of energy increased to 10 cents per kWh (gas prices are increasing) then the payback period would be around 18 years.

The long payback period is mainly due to the high interconnectedness of the Red Line with other CTA Lines, thereby meaning there is usually already a load (in terms of another train) to accept regenerated braking energy. The optimum place for a WESS would be on a single line that is not connected to any other lines.

A better candidate for a WESS would be the Blue and the Orange Lines when the new 7000 series in the following locations:

- Between Sacramento TPSS and O-Hare TPSS on the Blue Line;
- Between Kolmar TPSS and Des Plaines TPSS on the Blue Line;
- Between Ashland TPSS and Midway TPSS on the Orange Line.

Mott MacDonald would recommend CTA commission studies to examine the installation of WESS on these lines alongside the new 7000 series rolling stock.

As a stand-alone WESS on the Red Line is likely to be cost prohibitive based on regenerative braking energy savings alone, CTA should consider a Contract with a third party where that party is willing to pay for the capital cost of the WESS in order to participate in the Frequency Regulation Market (FRM). The WESS would be programmed to favor the FRM, but would still recover some wasted regenerative braking energy, which would be “free” energy savings for CTA. Any profit from participating in the FRM would be shared between CTA and the third party.

1 Abbreviations

Abbreviation	Name
A	Ampere
CTA	Chicago Transit Authority
DC	Direct Current
FRM	Frequency Regulation Market
kW	Kilowatt
kWh	Kilo Watt-hour
MW	Mega Watt
PJM	Pennsylvania Jersey Maryland
RTA	Regional Transportation Authority
SEPTA	Southeastern Pennsylvania Transportation Authority
TPSS	Traction Power Substation
V	Volts
WESS	Wayside Energy Storage System

2 Project Background

2.1 Project Description

In an effort to improve operational efficiency, the Chicago Transit Authority (CTA) and Regional Transportation Authority (RTA) have requested Mott MacDonald assess the effects of installing wayside energy storage systems (WESS) on the CTA rail system along the Red Line.

WESS are used in conjunction with electrically-powered rail transit vehicles equipped to utilize regenerative braking. A train equipped with regenerative braking uses the electric motors as generators to produce power and provide a braking force. However, in order for the generator (motor) to provide a braking force to the train the power produced by the generator (motor) must be spent. The power is consumed in three ways:

1) The train powers its own auxiliary load;
2) The train outputs power back onto the 3rd rail which can be consumed by other nearby receptive loads (e.g., trains, signaling loads or WESS); or
3) The power is wasted in on board resistors (rheostatic braking).

The trains will use the regenerated power to provide power to their own auxiliary load first and then try to output excess power to the 3rd rail. Any power that cannot be exported to the 3rd rail is wasted into the onboard resistors.

In order to reduce the wasted energy in rheostatic braking, the electrical traction network needs to be made more receptive. In this case, this is achieved using the WESS, which will be able to absorb regenerative braking energy from the 3rd rail.

The most common types of WESS are (in no particular order) batteries, capacitors and flywheels, although this report does not suggest that CTA limit itself only to these technologies.

2.2 Scope

2.2.1 Load Flow Analysis

The first part of the project was to undertake a Load Flow Analysis of the Red Line using Mott MacDonald's TRAIN software to produce a quantitative assessment of locations that would be optimum to place WESS for the capture of regenerative braking energy. However, the Red Line was not the only alignment modelled. CTA's extensive rail system, which includes subway, at-grade, and on-structure alignments, is powered by an all-inclusive traction power system. For example, the East Lake TPSS services both the Red Line and Blue Line Subway alignments, plus the downtown Loop alignment located on structure above the streets of Chicago. In the North Main segment, each TPSS services both the Red Line alignment and the Brown/Purple Line alignment that runs parallel to it.

2.2.2 Frequency Regulation Market

In addition to undertaking a Load Flow Analysis, Mott MacDonald was requested to advise CTA and RTA on the suitability of participating in the Frequency Regulation Market (FRM) in a similar manner to that of SEPTA.

As this participation cannot be simulated in TRAIN, the results and conclusions drawn on this part of the project derive from consultation with SEPTA, Constellation, Viridity, and ABB (the interested parties in SEPTA's participation in the FRM).

The FRM conclusions presented in this report are qualitative in nature, and are based on Mott MacDonald's best engineering judgement from talking with these firms.

3 Types of WESS

3.1 Types Of Storage Medium

A super capacitor is a high capacity capacitor that can store much higher charges, with lower voltages, than the standard electrolytic capacitor. There are no moving parts in a capacitor and as such super capacitors have a high efficiency of around 95 % (energy out / energy in). A WESS comprised of super capacitors will consist of hundreds of these capacitors arranged in series and parallel to achieve the necessary storage capacity. Super capacitors have a life time of between 10 and 15 years, but can be operated beyond this with an associated loss in storage capacity.

Flywheels store energy mechanically by spinning the flywheel to very high speeds (approx. 20,000 rpm). This is achieved by levitating the flywheel on magnetic bearings and maintaining a vacuum around the flywheel. The flywheel needs an auxiliary power source to maintain the vacuum, which affects their efficiency, which can drop to 92 % - 95 % (energy out / total energy in), once the auxiliary energy has been accounted for. Modern flywheels are designed to be failsafe if the vacuum or bearings fail so there is negligible risk to persons or property from a unit failing. Flywheels have a life time of between 20 to 25 years before the bearings will need to be replaced. The vacuum pump will need to be replaced approximately every 10 years.

A battery stores energy using an electrochemical reaction, where electrolytes form a reversible chemical reaction to allow the battery to either charge or discharge energy. There are many different types of battery, and the correct type would depend on the charge/discharge cycle, and required life time. Lithium Ion would tend to be favored due to the “no memory” discharge cycle, high charge density and low rate of self discharge. A large amount of Lithium Ion batteries will have safety implications in terms of fire, but this can be safely addressed in the design. Battery life is dependent on how many charge / discharge cycles and also on the depth of discharge. So increasing the storage capacity, for the same duty cycle, (to achieve a lower depth of discharge) will increase the number of cycles a battery is capable of achieving. Regardless, it is unlikely that a Lithium Ion battery life will be greater than five years.

In comparison, flywheels and capacitors are both able to accept and deliver charge at considerably higher rates than batteries (around 1000 times higher), and can tolerate more charge/discharge cycles to a greater depth than batteries. However, batteries have the advantage of a far greater energy per unit volume storage capacity than either capacitors or flywheels.

3.2 Energy Storage for Regenerative Braking

The energy requirements for regenerative braking require the storage device to be able to charge or discharge a “large” amount of power in a “short” period of time, but the total energy stored is “small”. The energy is stored for a short period time (around a minute usually) before the energy is discharged. This cycle can be repeated many times in an hour. The storage period is short because as soon as the load increases again (e.g., the train accelerates out of the platform) the WESS will start discharging.

This means the equipment has to cope with high power demands in between times of no power demand, which has led manufacturers to provide WESS such that the power rating quoted is the “peak” power (over a certain time period) and is not the continuous rating of the equipment.

Therefore, the power rating of the equipment is dependent on the load cycle of the WESS, and may be unique to each railway.

Both super capacitors and flywheels are capable of supporting these high power charge / discharge cycles, and either medium would be suitable for use on CTA for the capture and reuse of regenerative braking energy.

3.3 Energy Storage for Frequency Regulation

The energy and power requirements for the Pennsylvania Jersey Maryland (PJM) Frequency Regulation Market differs from that required for regenerative braking energy recovery in that the power requirements are “small”, but the energy requirements are “large”.

In the FRM, PJM sends a signal to all the participants requesting that they either increase or reduce the amount of energy they are taking from PJM. Once received, the controlling software then sends a charge or discharge signal to the WESS and monitors the incoming power supply to check that the signal is being accurately followed. However, as the WESS is connected to the railway it is not always possible for the WESS to follow the signal because:

1. The WESS may be full;
2. The WESS may be empty;
3. The WESS may not be able to charge from the grid.

Bullet points 1 and 2 are mitigated by only letting the WESS charge / discharge a certain amount, such that it will always have capacity to respond to the FRM, but this will have a detrimental effect on the amount of recovered energy from regenerative braking.

Bullet point 3 will occur sometimes because the WESS is connected to the DC busbar and the DC busbar is connected to the 3rd rail. When a train is regenerating it will push the DC voltage on the 3rd rail up, which (assuming the energy is not being fully utilized elsewhere) in turn will push the DC voltage on the busbar above the rectifier “no-load” voltage. This means that if the WESS receives a FRM signal to charge (at this point in time) it can’t achieve this as it is impossible for the rectifier to provide any current because the regenerating train is pushing the voltage on the DC busbar up. When the WESS charges, it cannot choose where the energy comes from, and by the very nature of the railway, the charge will always default to be coming from the regenerating trains as they push the DC bus voltage above the rectifier no load voltage.

How often the WESS is able to follow the FRM signal will affect the score the WESS achieves. Unless the WESS is able to achieve a score of around 90 %, but ideally 95 %, then it is unlikely to be asked to participate by PJM. Unfortunately, no one knows exactly how the score is worked out by PJM, but prioritizing the capture of regenerative braking energy at the WESS will negatively impact the FRM score.

While it is possible to install a WESS that is able to both participate in the Frequency Regulation Market and recover regenerative braking energy, the WESS will never be able to do both jobs simultaneously, or indeed be able to 100 % participate in the FRM.

The charge and discharge energy signals from PJM require a much smaller power requirement than the power requirement to recover energy from regenerative braking. The energy is also required to be stored for a longer period of time as the FRM signal from PJM should be energy neutral over 30 minutes.

This means that batteries are the ideal storage medium for a WESS that is participating in the Frequency Regulation Market, with possibly a small capacitor/flywheel storage to enable a small amount of power to be transferred and then “trickle” charged from these to the batteries. However, the exact makeup of the WESS storage medium for FRM would be recommended by the manufacturer.

There are also other markets that CTA could participate in with PJM which include:

- Peak Load Contribution Management
- Utility Demand Management
- Economic Management
- Synchronised Reserve

None of these are likely to be as financially attractive as participating in FRM – probably worth about 25 % to 40 % of the FRM, but they could be discussed with any third party as an option, or additional to, participating in the FRM.

4 Simulation Results Summary

4.1 Modelled WESS technical data

The preferred size of WESS modelled in the simulations is a 2000 A (or 1.5 MW limit) WESS with a storage capacity of 6 kWh to 8 kWh. Figure 4-1 shows a simplified single line diagram for a WESS in a TPSS. The control power (125 V DC) for the WESS is not shown and additional HV circuit breakers and traction transformers and rectifiers are not shown.

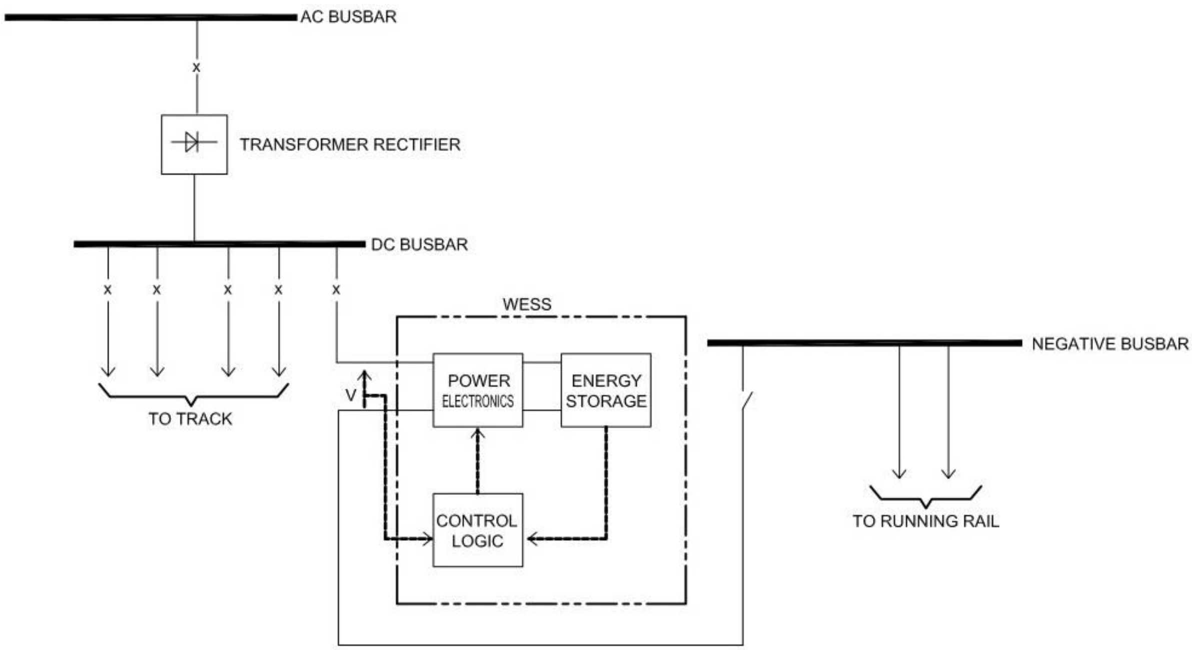

Figure 4-1: Single Line Diagram of a WESS

The WESS is controlled using four control voltages:

Vstartcharge – this the voltage on the DC busbar that triggers the WESS to start charging

Vtargetcharge – this is the voltage the WESS attempts to maintain on the DC busbar when charging.

Vstartdischarge – this the voltage on the DC busbar that triggers the WESS to start discharging

Vtargetdischarge – this is the voltage the WESS attempts to maintain on the DC busbar when discharging.

Vstartcharge > Vtargetcharge > Vtargetdischarge > Vstartdischarge

As the WESS is capturing regenerative braking energy, Vtargetcharge is set higher than the TPSS no load voltage to prevent the WESS from charging from the TPSS. Refer to the Load Flow Analysis report for the settings used.

In the TRAIN program the WESS is modelled in one of three modes:

1) IDLE

The WESS is neither charging or discharging

2) CHARGING

When the voltage at the TPSS busbar increases to the pre-set value, Vstartcharge, the WESS goes into charge mode. As the WESS draws power from the railway the voltage on the DC busbar will reduce. In charge mode the WESS will draw up to the maximum allowed current or power in an attempt to bring the TPSS busbar voltage down to the charging target voltage, Vtargetcharge. The WESS will continue charging until either it is full or the load builds up so that the charging current is reduced to zero in the attempt to maintain the busbar voltage target. The WESS will then return to IDLE mode when it has finished charging.

3) DISCHARGING

When the voltage at the TPSS busbar decreases to the pre-set value, Vstartdischarge, the WESS goes into discharge mode. As the WESS discharges power into the railway the voltage on the DC busbar will increase. In discharge mode the WESS will output up to the maximum allowed current or power in an attempt to bring the TPSS busbar voltage up to the discharging voltage target, Vtargetdischarge. The WESS will continue discharging until either it is empty or the load reduces so that the discharging current is reduced to zero in the attempt to maintain the busbar voltage target. The WESS will then return to IDLE mode when it has finished discharging.

4.2 Simulation Results

The full numerical results from the TRAIN program can be read in the report 369052/01/B Load Flow Analysis Report.

Mott MacDonald first simulated the existing Red Line to determine where trains where wasting the largest amount of energy in rheostatic braking. This was determined to be on the Dan Ryan part of the Red Line and Mott MacDonald agreed with CTA to examine the placing of WESS on the six TPSS along the Dan Ryan part of the Red Line.

The results from the TRAIN program showed that wherever the WESS was placed it was charging at its full capacity of 6000 A, but only discharging at around 3000 A. The WESS was also cycling through its full capacity of 12 kWh.

On the surface, the results show that the WESS is doing a great deal of work and cycling through a large amount of energy in each simulation. Indeed, the WESS reduces the energy consumed at its TPSS location between 80 kWh and 150 kWh per hour. However, intricate analysis of the traction power system as a whole shows that the energy consumed by the traction power system would only be reduced between 20 kWh and 80 kWh per hour. The energy output of the adjacent TPSSs would increase, which would partially offset the energy saved at the TPSS where the WESS is located.

Although Mott MacDonald has seen and advised other Clients on this phenomenon on other transit systems, this is particularly profound on CTA due to the high maximum regenerative voltage limit on the trains and the usage of composite conductor rail.

The Red Line operates at a nominal 600 V, with the TPSS “no-load” voltage of 645 V. The trains are capable of regenerating up to a maximum voltage of 800 V which is 1.24 times the “no-load” voltage of the TPSS, as compared to a 750 V nominal system where the maximum regenerative voltage is (900 / 790) 1.14 times the “no-load” voltage of the TPSS. Combine this with the installation of composite conductor rail and the Red Line trains are able to “throw” their regenerative braking energy significantly further than a system that operates at 750 V with steel conductor rail.

As an example, the loop resistance (3rd rail and running rail) is approximately 5.59 $\mu\Omega$/ft. A train that regenerates 4,000 A at 800 V can “throw” the regenerated energy ((800 – 645) / 4,000) / 5.59e-6 = 7,000 feet before a TPSS can even start to contribute to the load. This will be further exacerbated when the tracks in parallel are taken into account, resulting in a further reduction of the loop resistance. This means trains can probably reach out about as far as 12,000 feet with their regenerative braking energy in order to find a receptive load, which is almost two TPSS away.

If there is a WESS at one of these TPSS it “intercepts” this regenerative braking energy and absorbs the regenerative energy that would have otherwise gone to another train. The WESS is simply controlled by the voltage on the busbar and as this rises and puts the WESS into charge mode it draws current from the traction power system that would have gone to another train. This train then has to get its energy from elsewhere – the adjacent TPSSs.

Figures 4-2 and 4-3 show diagrammatically how this occurs. In this “scenario” the WESS is able to draw an additional 1000 A from the regenerating train, but intercepts the majority of the regenerative current. Train 2 now has to get the power from TPSS B, whose load goes up. Note that TPSS A is unable to contribute any power as the voltage on the DC busbar is always above the rectifier no load voltage.

The WESS is able to “drain” this current from the railway as the converter has active power electronics in it which form the buck-boost converter. The controller modifies the firing pattern of the active electronics to draw the correct current to meet the target voltage, Vchargetarget.

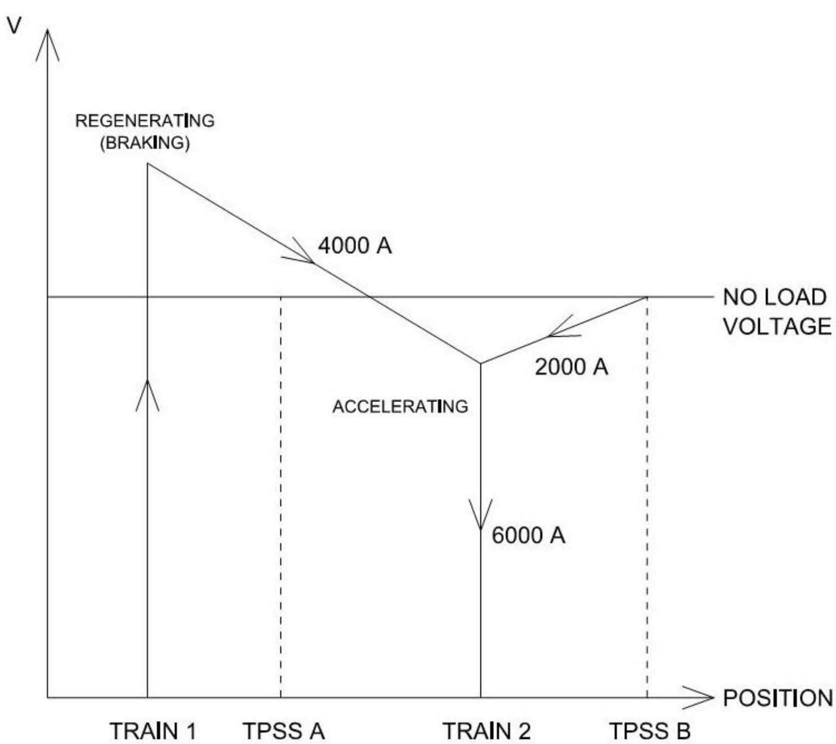

Figure 4-2: Regenerating train – no WESS

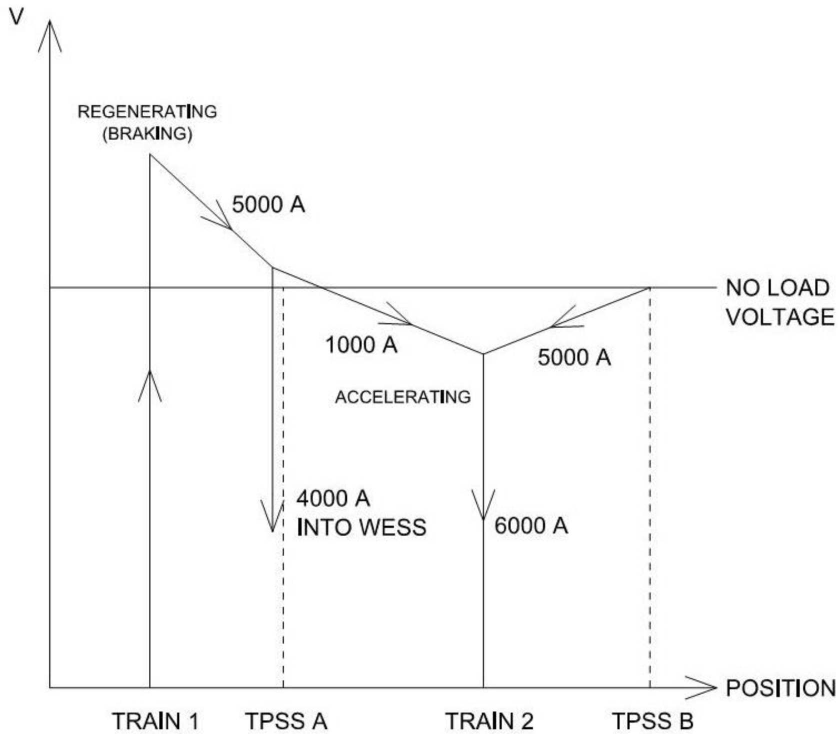

Figure 4-3: Regenerating train with WESS

Other factors that make the Red Line highly receptive are:

1) Relatively low headway (8 minutes) between trains during off-peak hours.
2) Cross connections to other lines around the Chicago Loop and on the North Main.
3) Cross connection to Green Line at Princeton TPSS.
4) Cross connection to Green and Orange Line at State TPSS.

All these reasons combined mean that the CTA Red Line is already highly receptive to regenerated energy. This can be seen as the place where the trains waste most energy in rheostatic braking is at 95th station which is away from the cross connections with other lines. Indeed around the city loop and the north branch of the Red Line there are many station to station links where negligible energy is being wasted in rheostatic braking. There are only five station to station links where more than 2 kWh of energy is wasted in rheostatic braking and three of these are at 79th, 87th and 95th stations. Indeed there is only a small amount of rheostatic energy wasted north of 69th Street station that can be pulled out of the trains and into a WESS.

4.3 Preferred Size of WESS

Based on the high receptivity of the CTA system, a 6000 A, 12 kWh WESS is intercepting too much regenerative braking energy that would otherwise have gone to other trains, and storing too much of this energy. The CTA system would be better suited to a smaller WESS to pick up the excess regenerative energy without interfering too much with the train-to-train energy transfer.

Based on this analysis Mott MacDonald undertook simulations examining the placement of a 2000 A 7 kWh WESS at 79^{th} TPSS and 95^{th} TPSS.

Based on an assumption of 20 peak hours and 148 off peak hours a week this gave an annual energy saving of 255,000 kWh with the WESS at 79^{th} TPSS. This figure is likely to be slightly conservative as the WESS will save more energy during the night when the service is below off-peak levels. However, it was not within Mott MacDonald's scope to model the overnight service.

4.4 Accuracy of simulations

The simulations undertaken by Mott MacDonald are as accurate as can be reasonably undertaken. There are, however, some factors that are not modelled in the simulation.

1) The TRAIN program ignores that some energy must be wasted in rheostatic braking as this is required to seamlessly blend between regenerative braking and friction braking. However, this is small in the overall scheme of things.
2) The TRAIN program assumes all the energy from regenerative braking can be exported to the line. This is not always the case because usually the electrical protection on the trains backs the regenerative current off as the voltage approaches the maximum over voltage.
3) There are unscheduled miles, e.g., for special events, that have not been accounted for when working out the annual energy savings from a "typical" week.
4) There are unscheduled delays and perturbations that, statistically, will occur at some point in the year that have not been accounted for when working out the annual energy savings from a "typical" week.

4.5 Financial Analysis

Although the exact cost of a WESS will vary between manufacturers and technology, the approximate cost of a 2000 A WESS with 8 kWh of storage energy will be around $700k. This is broken up roughly as $600k for the WESS and $100k for installation in the TPSS. Reducing the storage capacity to 6 kWh would probably save around $100k, but this saving would vary between manufacturers.

The quoted cost has been approximated from figures provided by the manufacturers that Mott MacDonald has talked to.

The $100k for installation would cover the cost of the following work in the TPSS:

- New DC circuit breaker and cabinet
- DC cabling and ladder tray between DC switchboard and WESS
- SCADA connections
- 125 V DC power supply connections to the WESS
- Any lighting modifications
- Testing and commissioning of the WESS

Table 4-3 in the Load Flow Analysis Report 369052/01/B shows the annual energy saving to CTA for one WESS at 79^{th} TPSS will be in the region of 255,000 kWh. The savings on the energy bill from Commonwealth Edison will depend very much on how CTA is billed for the energy which is usually a combination of a "peak" power demand as well as actual energy used. However, just considering the reduction in energy, at a cost of 7c per kWh, the annual saving for CTA would be in the order of $18k. There are likely to be additional cost savings including reduction in demand charges and higher energy savings during the night (which weren't modelled). However, this is only likely to increase the annual saving to around $25k to $30k.

This calculates out as a payback period of around 20 years, which would now have to factor in additional maintenance costs like the replacement of the capacitors or the vacuum pumps and bearings. This is likely to push any return on investment up to around 25 years, which is unlikely to be attractive.

The payback period is high not only due to the inherent high receptivity of the CTA system, but also due to the low cost of energy CTA already pays at 7 cents per kWh.

5 TPSS Site Survey Summary

As the simulations show that technically 79th TPSS is the preferred site for a WESS due to the availability of regenerative energy, this section concentrates more on describing the site visit to this TPSS.

5.1 WESS Suitability

The full site survey results with corresponding layout drawings can be read in the report 369052/02/B Site Survey Report.

The survey report shows that there is room in any of the six TPSS visited to install a WESS to install either type of WESS, but there would be restricted room at 79th and 95th TPSS to expand the WESS at a later date.

From a physical perspective, the preferred sites for the WESS would be 27th, Pershing or 50th TPSS as these sites have ample space for the WESS and two of these TPSS (Pershing and 50th) also have a complete spare DC circuit breaker and cabinet that can be used that would reduce costs.

5.2 FRM suitability

In order to participate in the FRM, an additional 500 kWh battery storage unit would be required. None of the TPSS surveyed have space internally to accommodate 500 kWh of battery storage.

However, this can be delivered to site in a self-contained 20 foot container and installed on a concrete slab with aerial cable tray between the TPSS and the container. It is this solution that Mott MacDonald has envisaged when checking the TPSS site suitability for participating in the FRM. The WESS would need to be expanded with an additional converter rated at between 500 A to 1000 A continuous current rating.

Although the exact type of batteries to be used would need to be confirmed by the manufacturer it is likely that these would be lithium-ion batteries and as such would need careful handling and safety precautions – although some precautions, like fire suppressant, can be incorporated into the container by the manufacturer.

From a physical space perspective, the preferred sites for the inclusion of a 20 foot battery container would be 27th, Pershing or 50th TPSS as these sites have space inside the TPSS fence for the battery container that would either negate the need for planning department permission or make it more likely to be granted, as well as there being no issue over land ownership and potential acquisition of adjacent property.

At 79th TPSS there is space to the east of the TPSS that is presently a flat, grassy area where a 20 foot container could be physically installed. CTA will need to confirm if they own the land, vehicle bollards will need to be installed around the container to prevent vehicular collisions and a tree may need to be removed. Other topics to be addressed are planning department permission and the installation of a potentially hazardous 20 foot container (it is an urbanized area that is open to view from the public).

6 Conclusions and Recommendations

6.1 Size of WESS

CTA need to note that each manufacturer provides the converter and energy storage medium in different “modules” such that any bids that come back from manufacturers may not exactly match the 2000 A current requirement and 6 kWh to 8 kWh energy storage requirement – it could be slightly more or less depending on what works within 79th TPSS limitations and constraints as imposed on their equipment. Any differences from these sizes should be duly considered and not rejected out of hand for not meeting the specification.

Also, different manufacturers have different sizes of equipment and different ways of putting them together. The manufacturers with whom Mott MacDonald spoke with as part of this project stated they would be willing to customize their equipment to fit any difficult space requirements. Therefore, any Request For Proposal to supply the WESS should be written cognizant of this, and should allow the manufacturers the opportunity to visit 79th TPSS so they can assess the space available for themselves.

The payback period based on regenerative braking energy saving alone for a 2000 A 6 kWh WESS at 79th TPSS is around 25 years. This is due to the high interconnectivity of the Red Line with the other CTA lines (meaning the system is already highly receptive to regenerative braking energy) and the low price of 7 cents per kWh CTA pays for electricity.

6.2 Participation in FRM

It is difficult for Mott MacDonald to definitively advise CTA on whether it is financially viable to pay for the necessary equipment to participate in the FRM or definitively size the WESS for the FRM as:

- this is not part of the TRAIN model;
- the information provided to Mott MacDonald has been qualitative in nature.

However, the revenue generated for participating in the FRM has generally correlated to natural gas prices and these are expected to increase by about 25 % over the next 10 years. Also as mentioned above, the WESS has to be “balanced” between performing in the FRM and recovering regenerative braking energy, which will always lead to a finite (albeit manageable and acceptable) reduction in the FRM score.

Mott MacDonald would therefore recommend CTA to issue any Request For Proposal with the option to participate in the FRM, and attempt to obtain a Contract, whereby other Parties pay for the capital cost of the equipment, and the profits are shared between the companies involved and the CTA.

6.3 Potential for WESS on other CTA lines

The potential for WESS on the CTA Red Line is limited mainly due to the high electrical interconnectivity of the Red Line with other lines that ensures the Red Line trains enjoy a high receptivity for their regenerative braking energy. WESS are most effective where there are no other loads already present – i.e., on a length of line that is not interconnected with other lines and has a headway greater than (approximately) ten minutes. In order to produce regenerative braking energy, trains must be braking, so any potential TPSS for WESS deployment would also need a station within (approximately) 3,000 feet of the TPSS.

When the 7000 series trains are introduced on the Blue and Orange Line in future years, there is the potential for WESS to be used on both of these lines. The WESS could be used in two ways:

1. To reduce capital TPSS upgrades.
2. To increase receptivity to regenerative braking to reduce energy usage.

WESS can be used to reduce capital TPSS upgrades by installing WESS either at midpoints or at TPSS and using them to trickle charge from the traction system. When a train goes past, the WESS discharges completely, thereby reducing the load on the TPSS and increasing midpoint voltages. This can mean additional transformer rectifiers don't need to be installed at existing TPSS or additional TPSS don't need to be built to support low midpoint voltages.

Mott MacDonald would recommend CTA commissions a Load Flow Analysis to examine the possibility of installing WESS alongside the introduction of the 7000 series trains:

- Between Sacramento TPSS and O-Hare TPSS on the Blue Line;
- Between Kolmar and Des Plaines TPSS on the Blue Line;
- Between Ashland and Midway TPSS on the Orange Line.

The other places that may benefit from WESS are:

- Between Western TPSS and Harlem TPSS on the Green Line.
- Between 17th TPSS and 54th TPSS on the Pink Line.

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