Eisenhower-Johnson Memorial Tunnel (EJMT) 2400v Motor Control Center Refurbishment
Hatch Mott MacDonald
White Paper
Sole Sourcing Review of the EJMT's MCC Switchgear

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Purpose

The purpose of this paper is to review whether sole sourcing is necessary for the replacement of 2400v Motor Control Center (MCC) equipment at the EJMT Tunnel, which is located in the State of Colorado. This paper identifies the following:

- Background to the EJMT's ventilation system;
- The MCC replacement alternatives being considered by the Colorado Department of Transportation (CDOT);
- The specific steps taken to determine whether or not sole sourcing is required; and
- Conclusions based upon the information that has been developed.

During the meeting of June 2, 2009, CDOT identified its concerns related to energy efficiencies of the existing EJMT ventilation fan motors. In response to CDOT's concerns Hatch Mott MacDonald (HMM) has identified some of the advantages and disadvantages of installing Variable Frequency Drives (VFDs) as part of the MCC refurbishment.

Background

The EJMT's ventilation system consists of six supply and six exhaust fans. The fans are housed in plant rooms located at each end of the tunnel. The East Ventilation Plant Room houses three supply and three exhaust fans. This arrangement is replicated at the west ventilation plant room. Each fan is driven by two dual-speed motors, with motor one rated 600/100 HP and the second motor rated 200/25 HP. The gear drive units and the CECON (Completely Enclosed for Continuous Operation) clutch, is configured for pollution control to start the 100 HP motor first to overcome fan inertia, before reverting back down to the 25 HP motor operations.

The larger motors are designed to operate during a fire to provide smoke control. The smaller motors are designed to exhaust vehicle emissions, as well as, smoke in the event of a fire. Under normal conditions, full speed, 600HP, fan operation is not required. The EJMT Fire Emergency Ventilation Study (Sverdrup, May 24, 2001), identifies that under conditions of good visibility, Monday – Friday, tunnel operators switch on two of the 200/25HP fans. During poor visibility, and on Sundays and Holidays, all 12 fans are operated at 100 HP.

Ventilation requirements in the South (Johnson) Tunnel are generally lower than in the North (Eisenhower) Tunnel. A prevailing West to East wind moves in the direction of traffic in the South Tunnel, and contributes to the tunnel's ventilation.

The tunnel ventilation system can perform smoke control with one fan out of service (EJMT Fire Emergency Ventilation Study, Sverdrup, May 24, 2001).

The MCC replacement alternatives under review are:

- **Option 1 - New Panels, With Temporary MCC during Construction**
  As identified by the Electrical Inspection Report (PB, July 2006), this option would include the installation of a temporary MCC line-up necessary to maintain tunnel ventilation during the changeover period. The temporary MCC line-up would allow existing MCC functionality to be transferred to the temporary line-up, thus freeing up the existing MCC line-up for permanent replacement. Upon completion, the temporary, redundant MCC line-up would be removed.

- **Option 2 - Partial Refurbishment**
  Option 2 involves the retrofit of existing MCC components and the retention of the existing MCC cubical sheet metal shells. This alternative would involve the refurbishment of the components located in a single MCC cubicle and would utilize the existing MCC footprint.

- **Option 3 - New Panels Sequenced (modular replacement)**
  To allow staged fan operations during construction, this option includes the retrofitting of existing MCC components and sheet metal shells in the existing MCC footprint. This alternative would involve the refurbishment of a single MCC cubicle at a time. The difference between Option 3 and Option 2 is that the sheet shell and main bus is replaced for Option 3.

- **Option 4 - Full Refurbishment**
  Option 4 involves a new MCC line-up that would be located on a new MCC footprint. The new MCC line-up would be commissioned into service and allow existing MCC functionality to be transferred to the new line-up. Upon completion, the existing MCC line-up would be de-commissioned. This alternative requires a new MCC footprint to be made available in the existing Tunnel Services Buildings.

Review of MCC Panels

In order to determine whether sole sourcing is necessary, HMM has liaised with the existing MCC manufacture General Electric (GE), as well as alternate switchgear manufacturers; Square-D, Powel and ABB. The objective of these discussions was to confirm whether or not the existing MCC can accommodate the two retrofit alternatives; Options 2 and 3. This liaison was necessary to address technical limitations of retrofitting existing equipment, in the existing switchgear footprint. The liaison included component sizing, bus bar compatibility, UL listing and fault ratings.

General Electric

GE visited the EJMT on June 25, 2009. The findings of their visit are summarized as follows:

1. Availability of spare parts for the present MCC presents problems as replacement parts are scarce;
2. Existing MCCs are dated 1967, and GE's latest MCCs are four generations past the existing;
3. Existing 44-inch width is a standard size for this type of equipment;
4. Existing bus very likely to be bolted between sections and not continuous, this would allow Option 3 be to implemented;
5. Clients preferred down time for a single MCC bus outage was eight hours. A single fan can be unavailable for a longer period;
6. Option 2 could be accommodated, but would likely require GE technicians on site to install the components, this results in increased cost for their site presence. In addition, space will need to be made available for local storage of electrical components, work space, tools and equipment;
7. GE can provide a UL listing for the replacement MCCs related to Options 2 and 3;
8. GE was advised of CDOT's requirement for compliance with the Buy American Act related to the steel cabinets;
9. Programmable Logic Control (PLC) could accommodate the replacement Options 2 and 3;
10. GE seems to recommend going with and is ready to support the implementation of Option 3, and,
11. GE can support Option 1.

Square-D

Square-D visited the EJMT on June 25, 2009. Square-D was provided with the pictures of the inside of the cubicles taken by GE. The findings of their visit are summarized as follows:

1. Square-D confirmed they could support Option 2. They indicated that they have worked with GE Limitamp gear before. Square-D indicated this option was labor intensive and would require multiple outages of between 16 and 24 hours;
2. Square-D confirmed they could support Option 3 replacement. Due to differences in bus placement and configuration, temporary transition sections may need to be employed. After all sections have been changed to Square-D gear the new line-up would be located in the same footprint. The need to replace all MCC sections would be constrained by retaining the lighting control cabinets. Square-D believes that this can be done in multiple outages of about 8 to 12 hours;

3. Square-D preferred supporting a modified Option 1. In this scenario a new MCC utilized for temporary operation at one end (say east) of the tunnel would later be installed permanently at the west end. For this scenario, once the new east MCC line up is commissioned on a temporary basis, the existing east MCC line up could be removed and transferred to the west on a temporary basis. A new final MCC line up could then be installed in the east. Once the west temporary MCC lineup is commissioned, the existing west lineup could be removed allowing a new east lineup, transferred from the east temporary, to be installed in the west as a final location. This would require the purchase of only four new MCCs without the additional expense of a temporary fifth MCC. This modified Option 1 (Option 1A) would require the temporary commissioning followed by decommissioning, relocation and then the permanent commissioning of one new MCC, and the careful decommissioning of one MCC that would be relocated for temporary use;
4. Square-D requested a copy of the PB Power Study and GE drawings. These were e-mailed to Square-D;
5. Square-D indicated that a UL label could be provided for the retro-fitted gear by having an UL inspector evaluate the final assembly. This is most applicable to Option 2.

Powell

Powell was provided with the GE drawings of the existing MCCs and some photographs, some of which were taken by GE during their site visit. The findings of their evaluation are summarized as follows:

1. Powell believes that they can come up with something to support either Option 2 or Option 3.
2. Powell has not provided definite details as to how they might be able to support at this time.

ABB

ABB was provided with the GE drawings of the existing MCCs and some photographs, some of which were taken by GE during their site visit. The findings of their evaluation are summarized as follows:

1. HMM has yet to receive a reply from ABB regarding their ability to support either Options 2 or 3.

Review of Variable Frequency Drives (VFD)

For many applications, VFDs can offer flexible motor control combined with significant electrical energy savings. A VFD manages the supply frequency and voltage, thereby regulating the magnetic flux of an induction motor. Advantages include:

- Low Inrush Current - By keeping the flux constant, the VFD quickly brings the motor up to full speed while limiting the inrush current, necessary to establish a magnetic field in the core, to 100 to 150 percent of its Full Load Amp (FLA) rating. Typically, the alternative Across-the-Line starting method can draw an inrush current of 600 percent FLA.
- Variable Speed and Reduced Power Consumption – A fan consumes power proportional to the cube of its velocity (3rd Fan Law), therefore a VFD operated fan running at 75 percent of full speed theoretically uses only 42 percent of full load power.

3rd Fan Law:	$\frac{HP_2}{HP_1} = \left(\frac{RPM_2}{RPM_1}\right)^3$
Reduce speed to 75 percent of full RPM:	$\frac{HP_2}{HP_1} = \left(\frac{75}{100}\right)^3$
42% of full load power consumed at 75% full RPM:	$HP_2 = 0.42(HP_1)$

In light of the above, the use of VFDs to start and control twelve fans with dual 600/100HP and 200/25HP motors may appear to represent potentially significant energy savings. However, the following disadvantages have been identified:

- Infrequent Use – The 600HP motors are only used for smoke control in the event of a fire, a typical ventilation mode will operate three exhaust fans at full speed and three supply fans at a reduced speed. Therefore, only six out of twelve fans are operated during a fire scenario. The large motors are started in tandem with the smaller 200/25 HP motors using a CECON clutch.
- Consistency Across System – The existing 480V Eisenhower Tunnel switchgear does not include VFDs. Having a system in place, which combines two sets of dual, two-speed motors with differing methods of motor control, introduces a layer of complexity that currently does not exist.
- Heat, Power Loss – VFDs introduce additional heat losses that currently do not exist. Forced ventilation that is currently not provided in the electrical switch rooms may be required to dissipate this additional heat.
- Harmonics - VFDs introduce harmonics that may affect the power quality of the motor circuits. Mitigating measures such as filter circuits may be required to mitigate harmonics.
- Design changes – The introduction of VFDs will require changes to be made to the existing control and interlocking mechanisms.
- Spacing Limitations – Options 2 and 3 would be contingent upon the ability of the supplier to incorporate the addition of VFD equipment and harmonic filters into the existing cabinet frame sizes. Additional space may also be required to house

ventilation. Siemens Rebicon's Medium voltage VFD requires 66"W x 42"D x 110"H without any by-pass contactor.

- The existing motors are 30+ years old, their insulation may not be as good as originally designed. New VFD's drives will likely be inverter duty designed to have higher insulation values on the windings. The existing motor winding insulation would need to be considered in the VFD design to ensure the motors are not faulted due to voltage spikes during operation.

Conclusions

<u>Sole Sourcing of MCC Equipment</u>

Options 1, 1A and 4: Options 1, 1A and 4 all include the installation of completely new MCC line-ups for which a number of manufacturers capable of fulfilling the requirements have been identified. Option 4 does not requiring sole sourcing since the option involves a new MCC line-up that would be located on a new MCC footprint. All potential vendors are American firms familiar with the Buy American Act.

Sole sourcing of equipment will not be required.

Option 2: GE, the manufacturers of the existing MCC line-ups has confirmed that they could provide refurbished MCC equipment for the existing cabinet frames (Option 2). Square-D has also confirmed the viability of Option 2 by stating that they could provide refurbished equipment that would fit into the existing cabinet frames. Both GE and Square-D can provide a UL listing.

Sole sourcing of equipment will not be required.

Option 3: GE indicated that they could support Option 3 and provide a modular replacement of the existing equipment and cabinet frames. In this scenario GE would not be constrained by the retention of the lighting control cabinets. Square-D has also indicated that they could carry out the modular replacement of the full cabinet line-ups in compliance with Option 3. However, at present it is believed that Square-D would be constrained by the retention of lighting control cubicles, but that these constraints could be overcome by the use of temporary transition sections. GE has confirmed that they can provide a UL listing. Whilst not specifically stated, it is likely that Square-D can also provide a UL listing for this option.

Sole sourcing of equipment will not be required.

As sole sourcing equipment is not deemed to be necessary for Options 1 - 4, a draft letter addressing FHWA concerns and supporting documentation with regard to this issue has not been prepared.

In response to the GE and Square-D conclusions above, it is necessary to confirm with the tunnel operator that a single MCC bus downtime of 8 to 12 hours is acceptable, as this will result in full ventilation being unavailable during this period.

Variable Frequency Drives

Any proposal to install VFDs would require the potential energy savings to be compared with the added capital and maintenance costs associated with changing existing controls and interlock designs, making space available for the new VFD equipment and providing forced ventilation and harmonic filters.

Based on the above review, it is HMM's opinion that the realized cost benefit associated with reduced energy use is unlikely to outweigh the additional capital costs.