Mobile Substations

Presented by:
Mr. Dan Boyd
Mr. Glen Rampaul
January 27, 2015

Agenda

- Topics:
  - Introduction
  - Applications
  - Pre-Design Considerations
  - Major Components
  - Options
  - Weight Savings
  - Sample Units
  - Questions & Discussion

Introduction

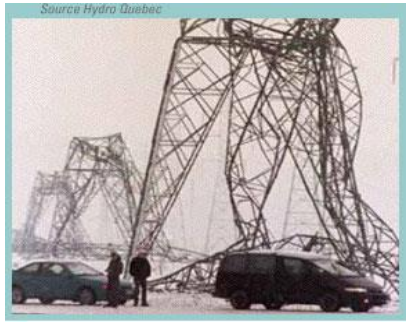
- Mobile Substation
  - As name implies, this is a substation on wheels
  - A mobile substation is a completely self-contained trailer mounted unit comprised of transformer, cooling equipment, high and low voltage circuit protection, metering, relaying, AC and DC auxiliary power supplies and surge protection

Introduction

- The mobile substation is intended to be pulled by a truck tractor and for that reason is mounted on a specially designed semi-trailer chassis
- The design and installation of a mobile substation have specific restrictions which are not present when designing conventional substations
- D.O.T. restrictions due to transport
  - such as limiting dimensions and weights
  - Road regulations
  - Electrical clearances

Applications

- Continuity of service for planned construction, maintenance and inspection programs
- Standby or temporary service
- Over-capacity service
- Replace complete substation in event of equipment failure
- Electrical power source in isolated areas
- Backup unit in countries with earthquake, flood, war, etc
- Power source for de-icing of HV lines in very cold areas



Pre-Design Considerations

- Once need is established, there are a number of different areas to be investigated before a specification is written and a proposed listing of equipment is developed
- The transformer is the largest, heaviest, and most costly component of the MSU. It is important to define the transformer parameters before continuing to other aspects of the mobile design. The transformer has the largest impact on the mobility of the mobile unit.
- Identify primary and secondary voltages, MVA requirement, highway and transportation regulations, high voltage and low voltage equipment requirements, and any physical restrictions that need to be addressed

Pre-Design Considerations

- The standard width of the mobile substation is 8’-6” with a height of 13’-6”. Larger mobile units will require special overweight and oversize permits
- The actual location of each substation to be investigated to determine and physical limitations and to note the location where HV section should be installed (front or back of trailer)
  - Typically HV section at back is most practical solution
- Several voltage configurations may be required to increase the flexibility of the MSU. However care should be taken so as not to increase the size and weight unnecessarily.

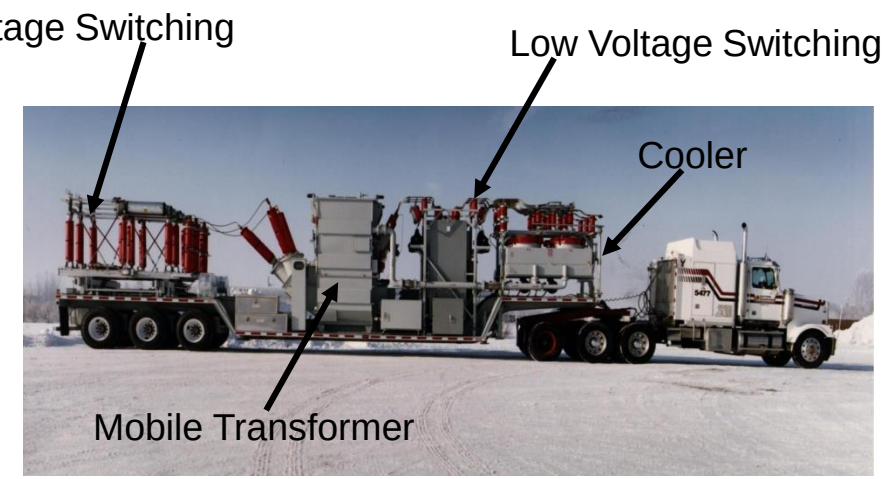
Pre-Design Considerations

- Not all mobile units are built as complete substations, but can be built as a mobile transformer only.
  - Primary reason to increase MVA but still be within DOT requirements
  - HV equipment is typically supplied on a separate trailer

40 MVA, 161.7 - 13.09 x 26.18kV
95ºC. Winding Rise

Major Components

- There are five major components of a mobile substation:
  - High Voltage Section
  - Transformer and Cooling
  - Low Voltage Section
  - Controls / Protection / Metering / Auxiliary Supply
  - Trailer – special design features



Power Transformer

- The Transformer is the main component of the Mobile Substation
- It is the largest and heaviest and most costly piece of the mobile substation.
- Mobile substation MVA and voltage combinations (HV and LV) are limited by DOT weight and dimensions restrictions.
- Mobile substations are generally rated 60 MVA or less.
- Hybrid Nomex Insulation is usually used for most mobile substations.
- Multiple voltages requirement (HV and LV) will add size and weight to the unit, thus reducing MVA rating of the transformer and mobile substation.
- LTC requirement will add weight and size to the mobile unit, thus reducing MVA rating of the transformer and mobile substation.
- Bottom mounted bushings to reduce overall height
- Compact construction by means of an optimized tank design.
- ODAF cooling for the transformer.

Power Transformer

- HV BIL reduction have great impact on mobile transformer weight and size reduction.
- LV BIL's usually are maintained at full level up to 25 kV, 150 kV BIL.
- Impedances for mobile transformer is much higher than a conventional unit. Typically they are 2 times the ANSI standard values.
- Losses are not evaluated for mobile transformer. The losses are much higher than conventional unit.
- Mobile transformer noise levels are typically NEMA standard. Lower noise levels should be avoided if possible because the cooler size and weight becomes excessive.
- The LTC is typically on the LV side for LV regulation. For multiple LV voltages, it is advisable to go with 2:1 ratio's LV's to avoid the requirement of a series transformer for the LTC. Because this will add weight and size to the transformer.

Power Transformer

Power Transformer

- 75°C or 95°C rise unit. This provides maximum capacity while keeping the weight to a minimum. Upgraded thermal insulation systems permit the higher temperature rise without sacrificing the life expectancy of the transformer (NOMEX Design).

- ODAF cooling consists of transformer oil coolers and circulating pumps. The cooling is automatically started by energizing the transformer. Without the coolers in operation the unit cannot carry load

Power Transformer

- The oil preservation system is sealed tank type with an optional inert gas system. Conservator designs can be considered for 550kVBIL or higher when road height allows. The transformer tank will withstand 15 PSI and full vacuum.

- Polymer bushings can be substituted for weight savings.

- Where there is multiple high voltage, externally operated de-energized switches are furnished to make series-multiple connections. In a similar manner a low voltage series-multiple or delta-wye switch can be furnished with the operating mechanism external to the tank to eliminate having to open the transformer.

Power Transformer

- Several switch options are available to increase the functionality of the transformer:
  - LTC
  - DTC
  - Series/Parallel
  - Delta/ Wye

Power Transformer

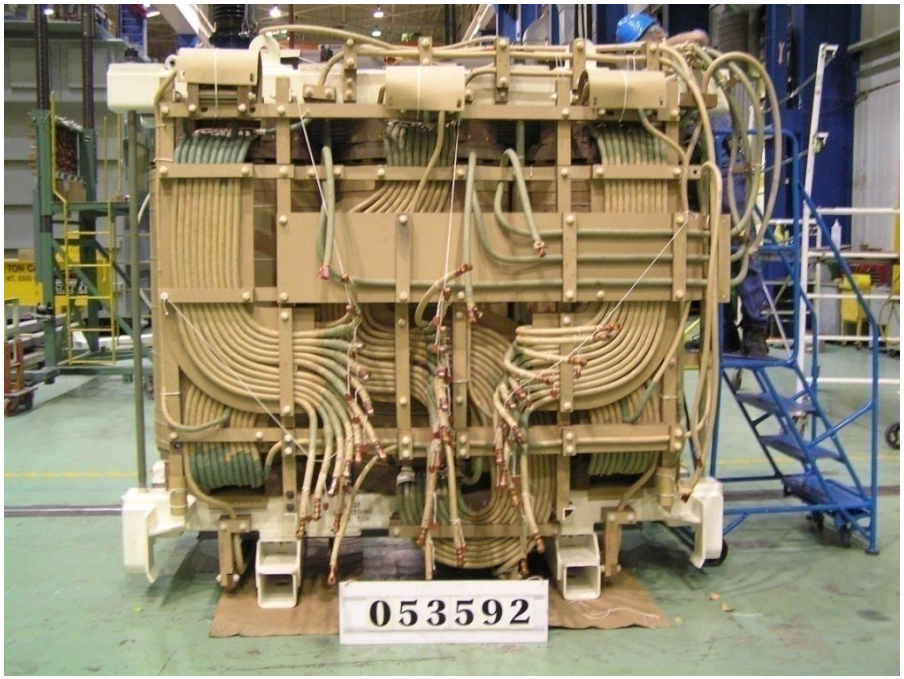
- Two types of load tap changers, resistive and reactive.
- Reinhausen MR RMV-II tap changer is reactive type LTC. This tap changer is suitable for current ratings up to 2500 amps. This type of tap changer will require a reactor.
- ABB UZFRT tap changer is resistor type. This tap changer is suitable for current ratings up to 600 amps. Application more than 600 amps rating will require a series transformer.
- Typical requirement for mobile transformer is LTC for LV regulation +/-10% in +/- 16 steps. This is normally done with MR RMV-II tap changer with reactor. This is a better option for mobile transformer because this is lighter / smaller than ABB UZFRT gear and series transformer.

Power Transformer

- LTC for multiple LV voltage, say 13.2 x 26.4 kV application, LV regulation +/-10% in +/- 16 steps for both voltages. In this case a series transformer will be required. This will add weight and size to the mobile unit.
-
- LTC for multiple LV voltage, say 13.2 x 26.4 kV application, LV regulation +/-10% in +/- 16 steps for 26.4 kV and +/-10% in +/- 8 steps for 13.2 kV. In this case a series transformer will not be required. This will help reduce weight and size to the mobile unit.

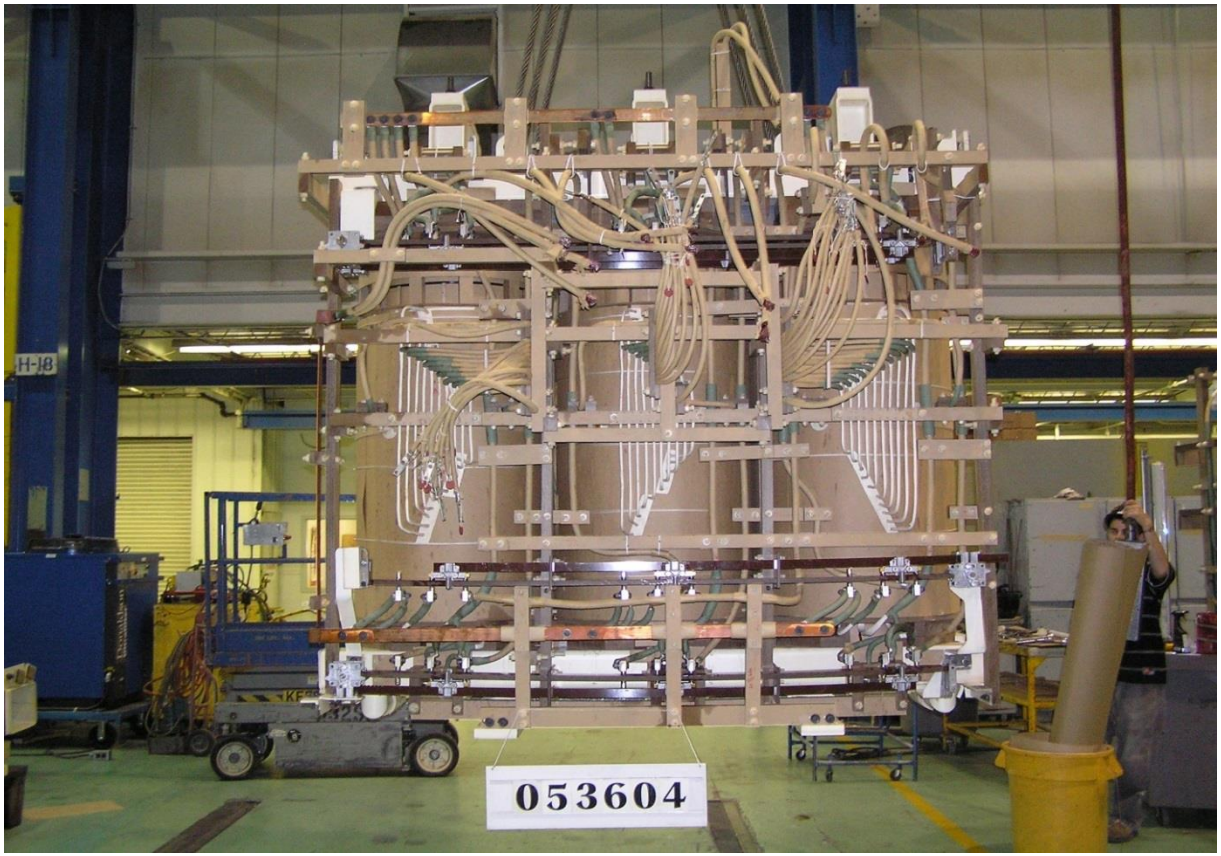
Power Transformer

- Core & Coil Assembly



Power Transformer

- LTC Leads & Cable Support



Transformer Cooling

- The heat exchanger system consists of one or two Brand X coolers. These are mobile transformer type oil coolers complete with copper liner tubes and aluminum extruded fins, pumps and fans. The system incorporates two pipe systems for the flow of the oil. The heat exchanger is designed to provide the maximum cooling efficiency. The cooling system can consists of two pumps and multiple fans . When one pump shuts down, the cooling system is capable of providing adequate cooling for continuous operation at 70% rated load indefinitely with no adverse or abnormal affect on the transformer. Pumps and fans shall not be controlled by winding temperature and must be energized during normal operation.

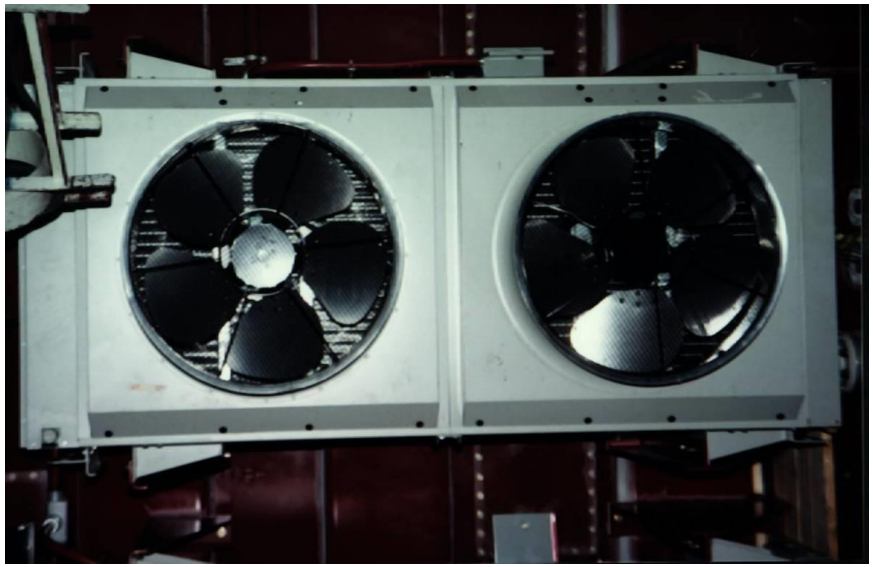
Transformer Cooling

- All piping between the transformer and the heat exchanger will be seamless metal and incorporate stainless steel flex joints to allow for vibration and expansion without any adverse effects. Pipe fittings and valves are suitable for high pressure applications.

- Oil flow sensors c/w alarm contacts are provided on each of the pipes to the heat exchanger.

Transformer Cooling

- Optimized orientation
- Transformer coolers
- All ridged steel piping and flexible stainless steel couplings for long life



High Voltage Section

- This section typically includes a combination of the following:
  - Circuit Breaker and Disconnect
  - Circuit Switcher
  - Power Fuses
  - Transrupter II
  - Surge Arresters
- Circuit Breaker and Disconnect Switch can be on a separate trailer (typical for 115kV and higher)
- Circuit Switcher can be on a separate trailer, typical when the weight and dimensions of the main unit exceed the specification or D.O.T. limits

High Voltage Section

- For voltages up to and including 38kV, MSU typically equipped with either a fused disconnect switch or vacuum circuit breaker with disconnect switch

- For voltages up to 69kV, the choice is typically a fused disconnect switch, circuit switcher, SF6 circuit breaker or Transrupter II.
  - Vacuum circuit breakers not available at 69kV and above

High Voltage Section

- For voltages up to 115kV and 138kV, a circuit switcher limited to 8 or 20kA is typical.
  - 25, 31.5, and 40kA circuit switchers not usable due to mechanical limitations
  - Candlestick circuit switchers are too tall for mobiles applications
  - For 40, 50 or 63kA, dead tank circuit breaker is required, typically making use of a second trailer necessary
- At 230kV, a separate HV trailer is most always required
- At present, breaker manufactures and gov't entities do not allow transport of SF6 breakers under pressure
  - Majority of gas is removed for transport
  - SF6 gas handling system is required to prep for transport and operation

High Voltage Section

Separate Mobile Circuit Breaker

Separate Mobile Circuit Switcher

Separate Mobile Transrupter II

HV Power Fuses on rear of Trailer

Low Voltage Section

- This section generally includes :

- Surge Arresters
- Potential Transformers
- Current Transformer
- Circuit Breaker and Disconnect
- Recloser
- Station service transformer
- Cable Reels
- Circuit Breaker is normally vacuum circuit breaker.
- Disconnect switches can be gang operated type or Hooksticks.

Low Voltage Section

- Cable Supports

Low Voltage Section

- LV Bus and Support Structure

Low Voltage Section

- Auxiliary Transformer, PTs, Fuse

Low Voltage Section

- External Auxiliary Transformer, Single phase, Multiple taps

Controls / Protection

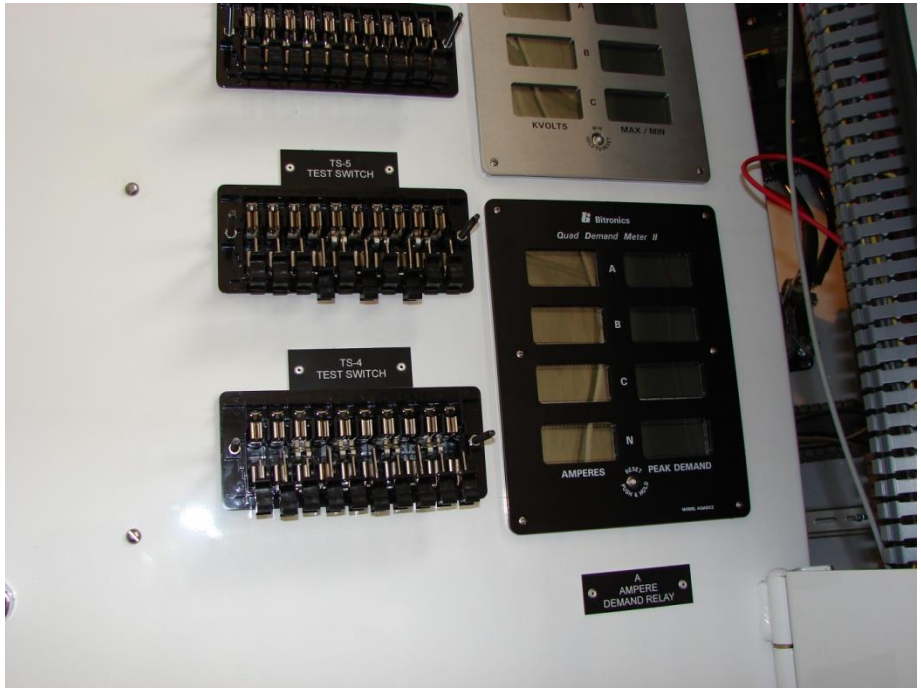
- This section generally includes :
- The controls, protection and metering is mounted in an outdoor cabinet. There are many protective relay's available. Transformer differential protection, over-current relays and sudden gas pressure relays are common. As the substation becomes more sophisticated so does the relaying.
- Main Control Panel (NEMA 4)
- Battery and Charger (Lead Acid or Ni Cd)
- RTU, SCADA
- Inverters

Controls / Protection

- Main Control Panel

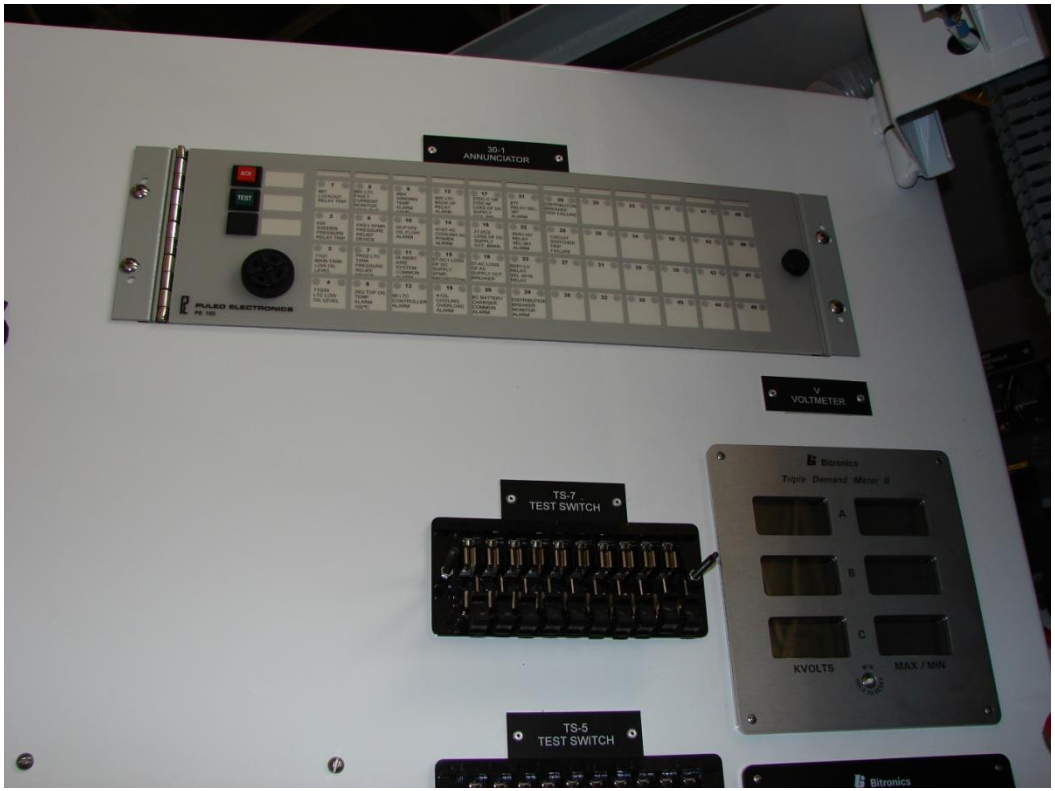
Controls / Protection

- Main Control Panel



Controls / Protection

- Main Control Panel

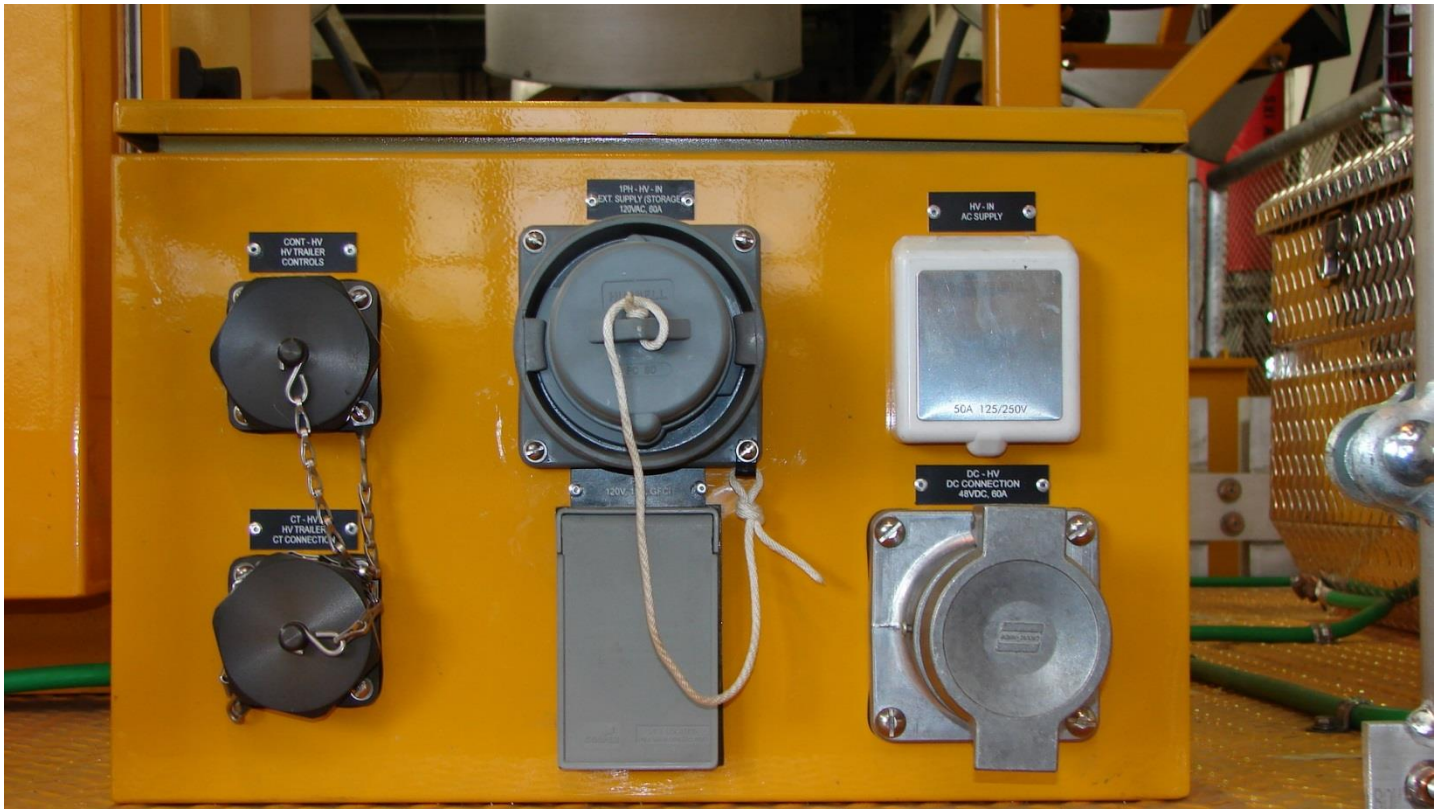


Controls / Protection

- Main Control Panel

Controls / Protection

- Interconnection between main and HV trailer



Controls / Protection

- Battery Cabinet

- Lead Acid Batteries takes up much smaller space than NiCad
- Typical size of cabinet for 125 VDC NiCad : 1600 lbs, 80 inches wide x 55 inches deep x 65 inches high.
- Typical size of cabinet for 125 VDC Lead Acid : 900 lbs, 40 inches wide x 26 inches deep x 41 inches high.

- Typical size of cabinet for 48 VDC NiCad : 550 lbs, 60 inches wide x 26 inches deep x 42 inches high.
- Typical size of cabinet for 48 VDC Lead Acid : 400 lbs, 30 inches wide x 27 inches deep x 40 inches high.

Controls / Protection

- Battery Cabinet

Controls / Protection

- Battery Charger

Trailer

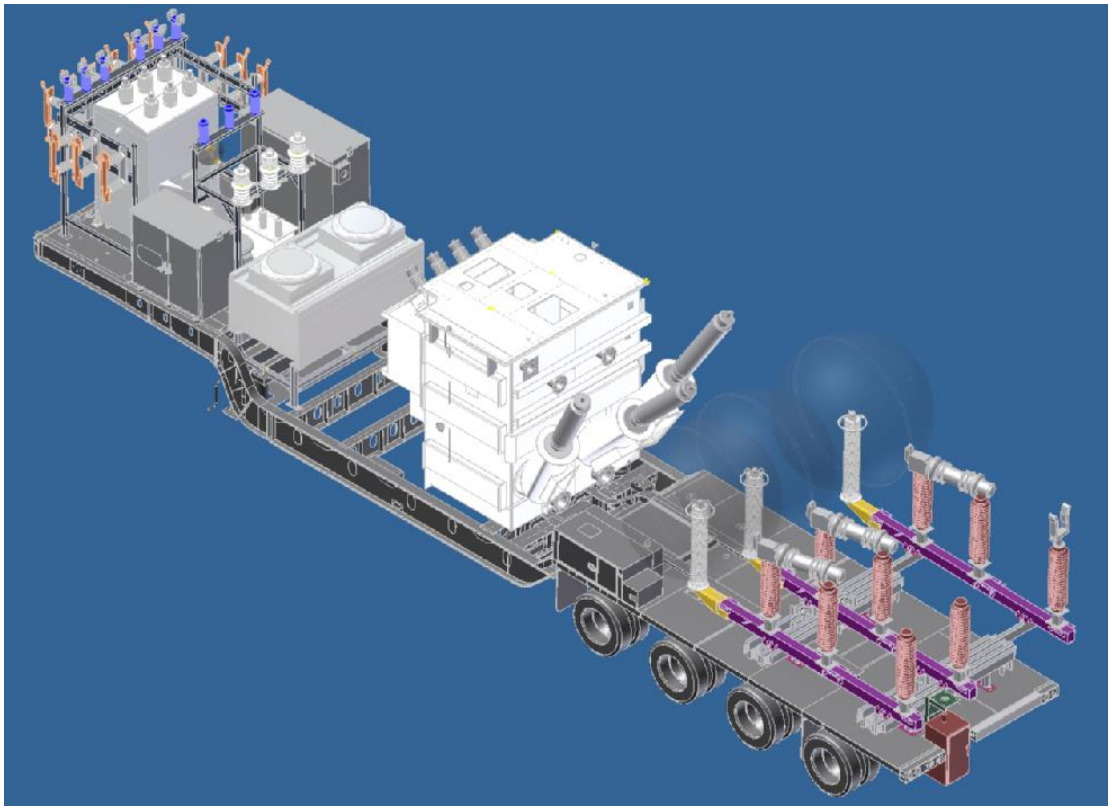
- The equipment trailer and the Purchaser's towing tractor together must meet the highway regulations of the States/Counties where the substation will be operated. The Purchaser may have to consider certain compromises on the substation design to obtain minimum weights and to meet highway operating regulations.

Trailer

- Typical trailer arrangements include multiple axles, jeep dolly and/or booster to distribute weight.

Trailer

- By proper location of the transformer and other apparatus the weight will comply with State DOT.

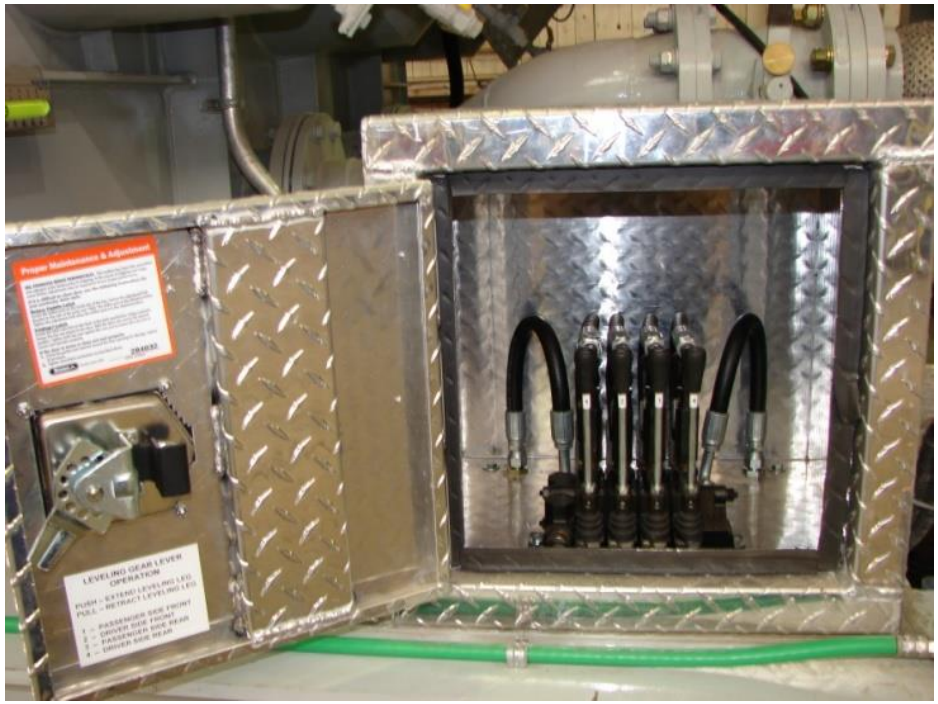


Trailer Features & Options

- Common features usually include:
- Steerable axles, air ride suspension and hydraulic leveling.
- Chock blocks for holding the trailer stationary when disconnected from the tractor.
- Towing eyes at the rear of the trailer.
- Other options:
  - LV Cable, Cable Reels, Cable Trailer
  - HV leads & connectors
  - Storage boxes
  - Cooler Guards
  - Spare tires / parts
  - Auxiliary generator

Trailer Features & Options

- Hydraulic Levelling



Trailer Features & Options

- Steerable Axles
  - Wheels turn left and right

Trailer Features & Options

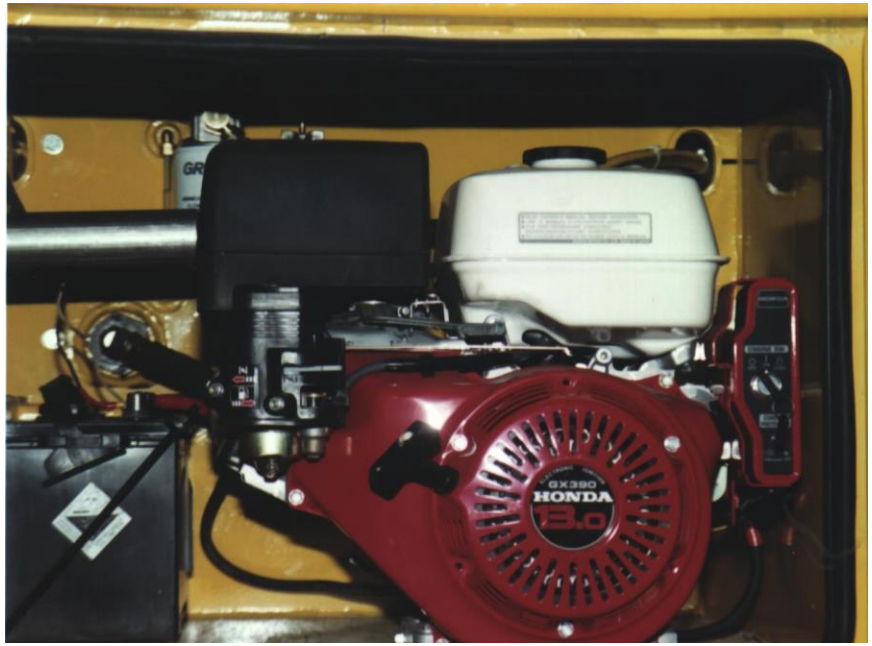
- Steerable Axles
  - Controlled with wired “pendant” style controller

Trailer Features & Options

- Steerable Axles
  - Wireless control available

Trailer Features & Options

- Gas Engine
  - Supplies power to operate pump
  - Pump connected at rear and reservoir in adjacent compartment



Sample # 1

- 40 MVA; 230 – 24.94 x 12.47kV with LTC; 95°C wdg rise

Sample # 2

- 45 MVA; 138 X 69 – 26.5kV with LTC; 95°C wdg rise

Sample # 3

- 33 MVA; 138 X 69 – 26.18 x 13.09kV with LTC; 95°C wdg rise

THANK YOU