Automatic Voltage Regulator (AVR) Placement for PSA Plants

Date: 8 January 2025
This document was developed by Build Health International to support global medical oxygen infrastructure planning, site preparation, operation, maintenance, and sustainability. Additional technical resources are available at www.bhioxygen.org.

Automatic voltage regulators (AVRs), often referred to as voltage stabilizers, are **highly recommended** to protect PSA plant equipment against overvoltage, undervoltage, and voltage surges by stabilizing the supply power voltage at the load. The purpose of this document is to provide guidance on the placement of AVRs within the electrical system supporting PSA plants, as well as specifications for appropriately sizing AVRs.

Background

The quality of electricity received from the grid often fails to meet the required nominal parameters, especially voltage. The fluctuations can be due to abrupt changes in loading or faults in the public network (e.g., overloaded transformers). A suitable operating voltage is essential to ensure the electrical components of PSA plants operate safely and reliably for their intended lifetime. Deviation outside each equipment's specified voltage range can lead to adverse effects. For example, an operating voltage that is too low can cause motors to draw more current than intended, leading to overheating, increased losses, and damage to windings. In extreme cases, the motor may stall during starting. On the other hand, high voltage can damage sensitive electronic devices in control circuits and accelerate wear and tear.

AVR Specifications

When specifying voltage stabilizers, some of the essential aspects to consider are:

- **Number of phases** *(single phase or three phases)*: This should match the connected load requirements.
- **Rated input voltage:** This should match the mains-rated supply voltage.
- **Input voltage range:** This will depend on anticipated voltage fluctuation values and voltage drop calculations. The AVR should be able to correct the expected input voltage fluctuation with a safety margin
- **Output voltage value and accuracy:** This will depend on the rated input voltage of the PSA plant
- **Phase regulation** *(independent or common)*: Independent phase regulation is preferable because it provides better phase to phase voltage balance.
- **Admitted load variation:** This is important as this is often witnessed when running PSA plants.
- **Admitted load imbalance**
- **Rated power capacity (kVA)**: The AVR's rated power should support the maximum input current under ordinary conditions, with a safety margin for possible future expansion.
- **Admitted overload:** The AVR should be able to accommodate momentary overloads, that is, the inrush currents/starting kVA of the PSA plant during motor starting.

- **Harmonic distortion:** Ideally, there should be minimum to no harmonic distortion introduced to the system.
- **Ambient temperature:** This should accommodate the expected temperatures at the site location.
- **Maximum humidity**: This should accommodate the expected humidity at the site location.
- **Protection degree** *(IP Rating):* Indoor or outdoor rated depending on installation location.

Additional components to consider on a case-by-case basis (usually listed as optional by manufacturers):

- **Bypass switches:** The internal bypass switch can be either manual or automatic. An external manual bypass switch is also recommended for complete isolation of AVR if damaged beyond repair and needs replacement
- **Surge protective devices:** This is important, especially if there is no surge protection upstream of the AVR
- **Overcurrent protective devices:** These are recommended, especially if there is no overcurrent protection upstream of the AVR or for the cable feeding the AVR.

Sample AVR technical specifications from various manufacturers can be found in Appendix A.

AVR Placement in the Power Distribution System for PSA Plants

This analysis only applies to the following scenarios:

1. *The proposed AVR is dedicated to the PSA plant*
2. *There is a dedicated generator and automatic transfer switch (ATS) for the PSA plant.*

Please note that generators typically have a built-in AVR system to maintain a constant voltage output.

1. AVR Placement before the ATS (on the utility side)

**See single-line diagram (SLD) 2 for illustration.*

Advantages

- Protects the ATS and PSA plant from damages due to voltage fluctuations from unstable utility power.
- Prevents nuisance changes of the ATS to secondary/Generator power in case of unstable utility voltage values exceeding the programmed ATS voltage tolerances.

Disadvantages.

- Does not offer protection to the PSA plant in the event of unstable voltages from a faulty generator.

2. AVR Placement after the ATS

**See single line diagram (SLD) 1 for illustration.*

Advantages.

- Protects the PSA Plant from damages due to voltage fluctuations from unstable utility power and a faulty generator.

Disadvantages.

- Does not protect the ATS from damage due to voltage fluctuation from unstable utility power.
- In case of unstable utility voltage values going beyond the programmed ATS voltage tolerances, there is a risk of nuisance changes of the ATS to secondary/generator power. This can have a number of detrimental effects, such as interrupted operations, lost productivity, downtime and possible equipment damage.

Factors Influencing the AVR Placement

1. **Utility Power Availability** - If the utility is unavailable or mostly unavailable, then the PSA plant will likely run mainly on the generator as the primary power source. It is therefore advisable to have the AVR after the ATS for this scenario.
2. **Utility Power Stability** - For locations where the utility is unstable, that is, experiencing frequent voltage fluctuations, it is advisable to have the AVR before the ATS.
3. **Type of Transfer Switch** - If a manual transfer switch (MTS) is used instead of an ATS, it is advisable to have the AVR after the MTS. This is because MTS will not exhibit nuisance tripping.
4. **Electronic Components:** If the ATS includes sensitive electronic components, it is advisable to protect it, hence placing the AVR before it, especially in areas where there is a possibility of voltage fluctuations.
5. **Generator Size** - if the generator has not been sized to fully handle the starting capacity (kVA)/startup inrush currents of the PSA plant, then it is advisable to place the AVR after the ATS to correct any anticipated voltage drops during the start-up of the motor components of the plant. However, the AVR input voltage tolerance specifications should be able to handle the anticipated voltage drops. It is advisable to size the generator to handle motor start-ups, and this rare case only applies to a generator already procured and which cannot be replaced.
6. **Generator maintenance** - For efficient operation and prolonged lifespan of the generator, it is always important to follow manufacturers' recommendations on maintenance. If frequent generator maintenance cannot be guaranteed, placing the AVR after the ATS is advisable. One of the causes of unstable voltages from generators is poor generator maintenance. It is also not advisable to tamper/bypass the safety features of the generator as this may lead to further damage to the generator and equipment protected.
7. **Generator fuel quality** - It is important to use quality fuel for diesel generators to ensure smooth operation without challenges. If quality fuel cannot be guaranteed, then it is advisable to have the AVR after the ATS to protect against any likely unstable voltages due to low-quality fuel.

Recommendations

Taking into consideration the advantages and disadvantages of each placement location as well as the factors highlighted above, below are the recommendations:

- Ensure proper maintenance of the generator. This can be achieved through the following;
  - Following manufacturers' guidelines and recommendations on generator maintenance.
  - An initial maintenance contract should be included after installation and commissioning by the supplier.
  - Tools and spares for generator maintenance should be included as part of the cost of the generator.
  - Training local technicians on troubleshooting, safe practices, routine checks, and proper preventive and corrective maintenance of the generators. As highlighted earlier, it is not advisable to tamper with or bypass the generator's safety features, as this may lead to further damage to the generator and equipment protected.
  - Ensuring only good quality fuel is used for the generator.
- Installation of over/under voltage protection relays, with time delay settings for utility and generator inputs. This protects against unstable voltages from both the utility and the generator (if AVR is placed before ATS).
- Specify an ATS that includes an adjustable input voltage tolerance (for utility/main source) with a time delay setting. This will usually prevent nuisance changeovers from the utility to the generator in case the utility becomes unstable within the set tolerances.

- Proper sizing of the generator to handle both the start-up and running capacity of the PSA Plant.

Appendix A

THREE-PHASE VOLTAGE STABILISERS

T MODELS
COMMON REGULATION OF THE 3 PHASES

MINISTAB T 3.5-32 KVA
STEROSTAB T 22-800 KVA

GENERAL CHARACTERISTICS

Mains	Three-phase
Nominal input voltage	380V or 400V or 415V (**)
Nominal output voltage	380V or 400V or 415V (**)
Output accuracy	±1% RMS
Frequency	50/60 Hz ±5%
Admitted load variation	0 to 100%
Admitted load unbalance	up to 50%
Admitted overload	10 times the nominal power during 10 ms, 5 times during 6 s, 2 times for 1 minute
Harmonic distortion	<0,1%
Efficiency	>98.5%
Cooling	natural air convection (fan-free system)
Colour	black or RAL 7035 (depending on model)
Protection degree	IP21
Installation	indoor
Standard fittings	digital voltmeter, pilot lamps, tropicalised control boards

(**) to be specified on the order. Different voltage values available on request.

Figure 1: IREM T-Model AVR datasheet with Common Phase Regulation

THREE-PHASE VOLTAGE STABILISERS

Y MODELS
INDEPENDENT REGULATION OF EACH PHASE

MINISTAB Y 3-120 KVA
STEROSTAB Y 45-8000 KVA

GENERAL CHARACTERISTICS

Mains	Three-phase
Nominal input voltage	380V o 400V o 415V (**)
Nominal output voltage	380V o 400V o 415V (**)
Output accuracy	±1% RMS
Frequency	50/60 Hz ±5%
Admitted load variation	0 to 100%
Admitted load unbalance	up to 100%
Admitted overload	10 times the nominal power during 10 ms, 5 times during 6 s, 2 times for 1 minute
Harmonic distortion	<0,1%
Efficiency	>98.5%
Cooling	natural air convection (fan-free system)
Colour	black or RAL 7035 (depending on model)
Protection degree	IP21
Installation	indoor
Standard fittings	digital voltmeter, pilot lamps, tropicalised control boards

(**) to be specified on the order. Different voltage values available on request.

Figure 2: IREM Y-Model AVR datasheet with Independent Phase Regulation

VOLTAGE STABILISERS
STEROSTAB T COMMON REGULATION OF THE THREE PHASES
THREE-PHASE 400V 50/60 HZ PROTECTION DEGREE IP21

Model	*Rated power (KVA)*	*Voltage variation (±%)*	*Response time (ms/V)*	*Output accuracy (±%)*
T310AN22	22	±30	10	
T310AN30	30	±25	11	
T310AN40	40	±20	13	±1
T310AN55	55	±15	14	
T310AN90	90	±10	28	
T312AN35	35	±30	6	
T312AN45	45	±25	15	
T312AN60	60	±20	12	±1
T312AN80	80	±15	16	
T312AN120	120	±10	23	
T314AN45	45	±30	10	
T314AN60	60	±25	14	
T314AN80	80	±20	13	±1
T314AN120	120	±15	17	
T314AN185	185	±10	22	
T315AN70	70	±30	14	
T315AN90	90	±25	18	
T315AN120	120	±20	23	±1
T315AN170	170	±15	24	
T315AN270	270	±10	36	

Figure 3: IREM Y-Model AVR datasheet indicating available input voltage tolerance ranges and response times

ORTEA NEXT

ABOUT US PRODUCTS SERVICE APPLICATIONS BL

TECHNICAL SPECIFICATIONS

Frequency	50Hz ±5% o 60Hz ±5%
Adjusting energy parameters	Independent phase control
Selectable target voltage	from 210V to 255V (L-N) / from 360V to 440V (L-L)
Output voltage accuracy	±0,5%
Admitted load variation	Up to 100%
Admitted load imbalance [%]	100
Cooling	Natural ventilation (from 35°C aided with fans)
Ambient temperature	-25/+45°C
Storage temperature	-25/+60°C
Max related humidity	<95% (non condensing)
Admitted overload	200% 2min.
Harmonic distorsion	None introduced
Colour	RAL 7035
Instrumentation	✓ Input & Output digital multimetre
Installation	Indoor
Overvoltage protection	✓ Class II output surge arrestors ✓ Optimal voltage return through supercapacitors in case of black-out

ORION PLUS ±10%

ORION PLUS ±20%/±15%

ORION PLUS ±30%/±25%

ORION PLUS +15%/-35%

ORION PLUS +15%/-45%

Figure 4: Ortea Orion Plus AVR datasheet

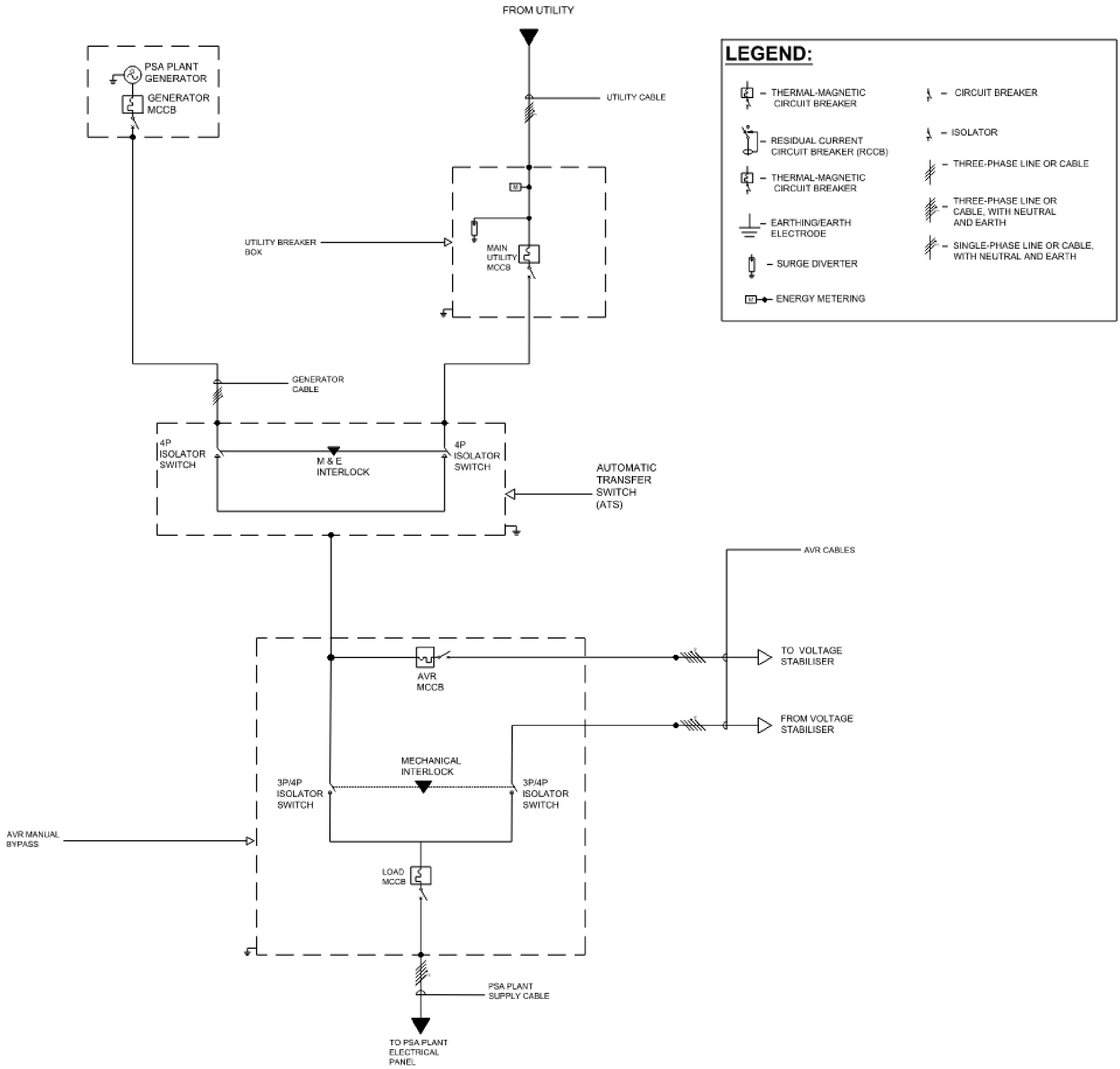

Figure 5: Example SLD 1 - AVR Placement after the ATS

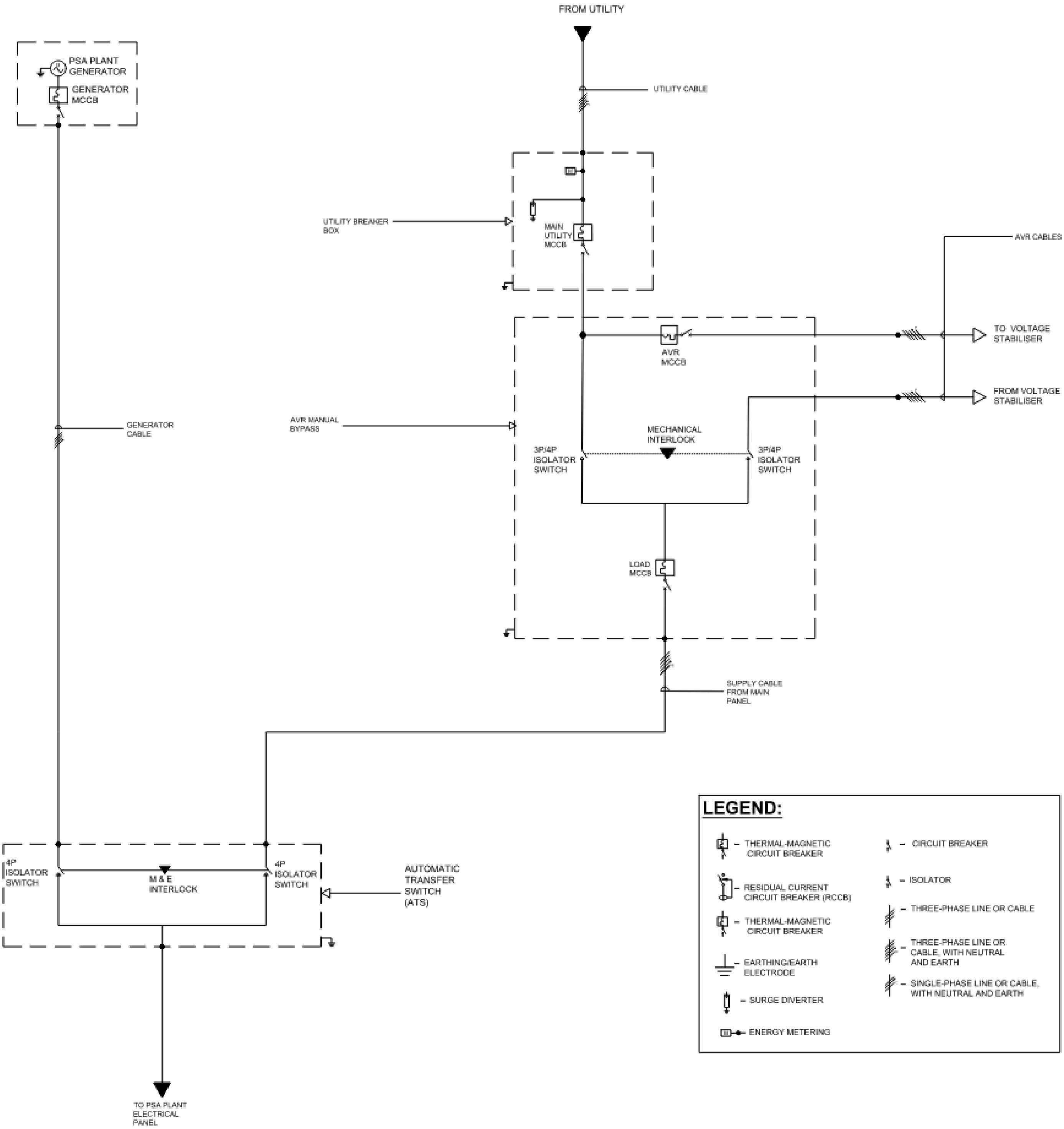

Figure 6: Example SLD 2 - AVR Placement before the ATS (on the utility side)