MA327 AUTOMATIC VOLTAGE REGULATOR (AVR)

SPECIFICATION, INSTALLATION AND ADJUSTMENTS

General description

The MA327 is a three phase full wave, pulse width modulated type automatic voltage regulator (AVR) and forms part of the excitation system for a brushless generator.

Excitation power is derived from a three-phase permanent magnet generator (PMG), to isolate the AVR control circuits from the effects of non-linear loads and to reduce radio frequency interference on the generator terminals. Sustained generator short circuit current is another feature of the PMG system.

The AVR senses the voltage on the main generator winding and controls the power fed to the exciter stator and hence the main rotor to maintain the generator output voltage within the specified limits, compensating for load, speed, temperature and power factor of the generator. Three-phase root mean squared (RMS) sensing is employed for superior voltage regulation.

Soft start circuitry is included to provide a smooth controlled build up of generator output voltage.

A frequency measuring circuit continually monitors the speed of the generator and provides under-speed protection of the excitation system by reducing the generator output voltage proportionally with speed below an adjustable threshold. A further enhancement of this feature is an adjustable volts per Hertz slope to improve engine recovery time on turbo charged engines.

Protection circuitry is included which cuts off the excitation power in event of over-voltage.

Excitation limiting is a standard feature allowing control over the amount of short circuit current flowing during short circuits of the generator output.

Uncontrolled over-excitation is limited to a safe period by internal shutdown of the AVR output device. This condition remains latched until the generator has stopped.

For complete protection, a miniature circuit breaker option is available, providing circuit isolation in the event of a short circuit AVR power output device.

Provision is made for the connection of a remote voltage trimmer allowing the user fine control of the generators output.

Technical specification

Sensing input

Voltage	170-250 Vac max
Frequency	50-60 Hz nominal
Phase	1 or 3
Wire	2 or 3

Power input (PMG)

Voltage	140-220 Vac max
Frequency	100-120 Hz nominal
Phase	3
Wire	3

Output (limited by PMG output)

Voltage	max 180 V dc (1800 rpm)
Current	continuous 6 A
Intermittent	12 A for 10 secs
Resistance	15 ohms minimum

Regulation

(4% engine governing) +/- 0.5% RMS

Thermal drift

0.015%V per degree centigrade change in AVR ambient

Soft start ramp time

0.5 - 4 seconds

Typical system response (AVR and generator)

Exciter current to 97% 300 ms

External voltage adjustment

+/-5% with 5 k ohm 1 watt trimmer

Under frequency protection

Set point	97% Hz
Slope	100-300% down to 25 Hz
Max. Dwell	10 % V/ Sec. recovery

Unit power dissipation

30 watts max

Accessory input

+/-1 volt input = +/- 5% generator volts

Quadrature droop sensitivity

0.04 Amps for 5% droop @ pf

Excitation limit

Setting range 50 - 100%

Over excitation protection

Setting range	60-90 V dc
Time delay	inverse time < setting = infinity >25 % setting = 10 seconds max

Over-volts protection

Setting range	250-350 volts
Time delay	1 second fixed

Circuit breaker trip coil voltage 10 to 60 V dc

Circuit breaker trip coil resistance 50 to 100 ohms

Environmental

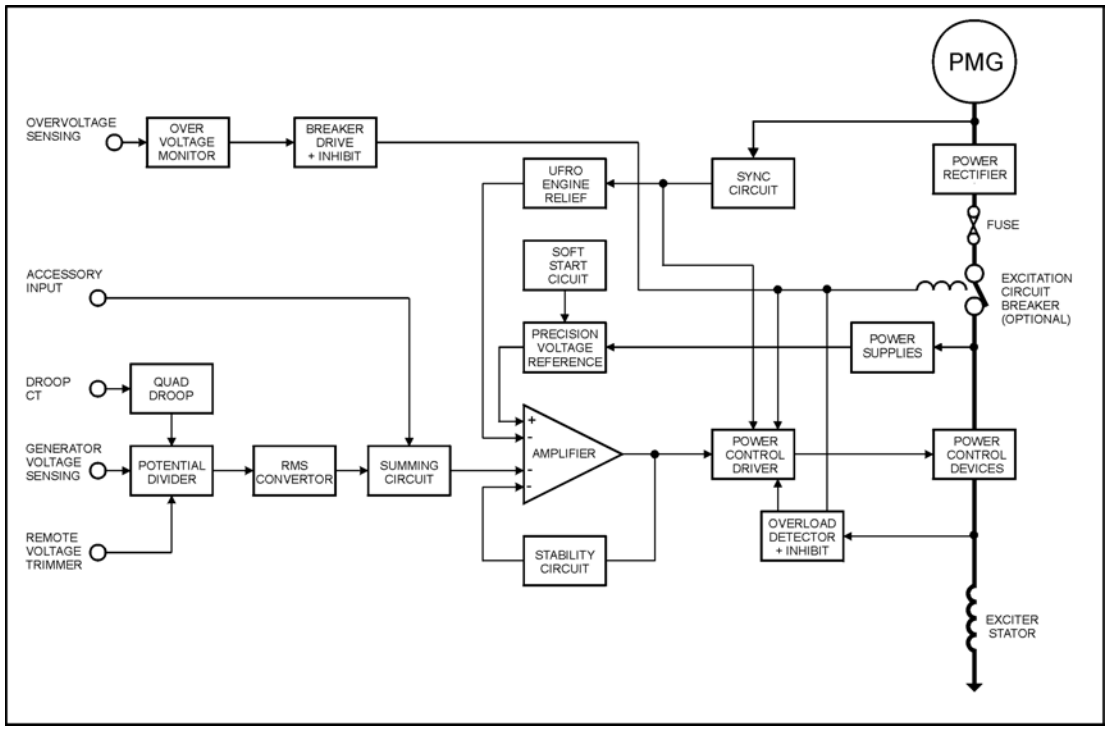
Vibration	5-10Hz	1mm pk
	10-100Hz	50mm/sec RMS
	100Hz-300Hz	4.4g pk
Relative humidity 0-70c		95%
Operating temperature		-40 to +70c
Storage temperature		-55 to +80c

Fuse rating

10 Amps 1.25ins. quick-blow ceramic CSA UL approved

Accessories are available for this AVR.

Design detail



The main functions of the AVR are as follows:-

Potential divider takes a proportion of the generator output voltage and attenuates it. Provision is made to allow the attenuation ratio to be adjusted by the internal AVR 'Volts' potentiometer or an external hand trimmer if required.

Quadrature droop circuit converts the current input from a CT into a voltage which is phase mixed with the sensing voltage. The result is a net increase in the output from the sensing network as the power factor lags, causing the reduction in excitation needed for reactive load sharing of paralleled generators.

RMS converter converts the AC signals from the potential divider into a DC signal representing the Root Mean Squared value of the wave form.

Summing circuit provides an interface between the AVR and accessories, usually a power factor controller, allowing the accessory output voltage to be summed with the sensing voltage for control purposes.

Power supply components consist of transformers resistors, regulator diodes and smoothing capacitors to provide the required voltages for the various electronic circuits.

Precision voltage reference is a highly stable temperature compensated voltage reference used for dc voltage comparison purposes.

Soft start circuit overrides the precision voltage reference during run up to provide a linear rising voltage.

Amplifier compares the sensing voltage to the precision reference voltage and amplifies the difference (error) to provide a controlling signal for the power device.

Stability circuit provides adjustable negative ac feedback to ensure good steady state and transient performance of the control system

Power control driver controls the conduction period of the output device using pulse width modulation techniques.

Power control devices vary the amount of exciter field current in response to the error signals produced by the amplifier and power control driver.

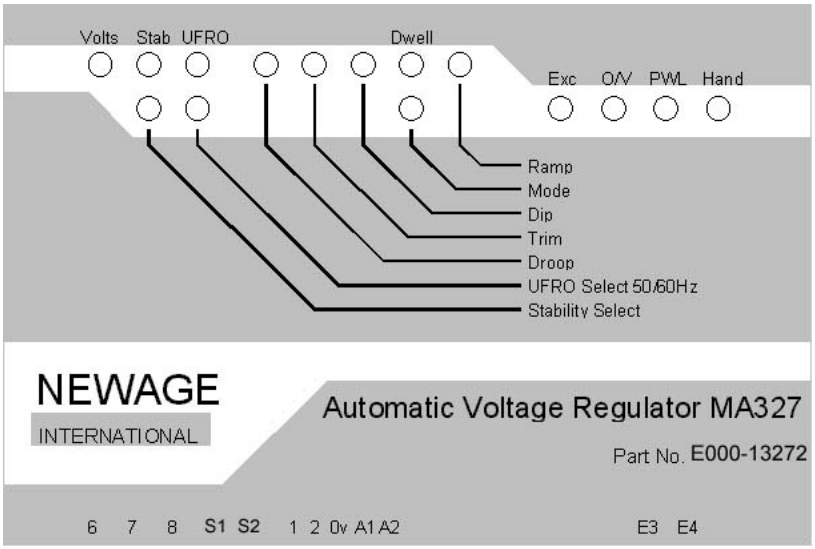
Sync circuit provides a short pulse to synchronise the Under Frequency Roll Off (UFRO) and power control circuits to the generator cycle period.

UFRO circuit measures the period of each electrical cycle and reduces the reference voltage linearly with speed below an adjustable threshold. A light emitting diode (LED) gives indication of under-speed running.

Engine relief or load acceptance circuit provides adjustment for increasing the voltage roll off (gradient of V/Hz slope), to aid engine recovery after the application of a block load. A "Dwell" feature is included which delays the rate of recovery of generator volts after application of load, providing further engine assistance.

Position of adjustments

Stability Table	
Switch position	
0 = under 100kW	5 = 2500 - 3200 kW
1 = 100 - 500 kW	6 = 3200 - 4000 kW
2 = 500 - 1000 kW	7 = 4000 - 4800 kW
3 = 1000 - 1800 kW	8 = not used
4 = 1800 - 2500 kW	9 = not used



Position of adjustments

Control	Function	Direction
Volts	To adjust generator output voltage	Clockwise increases output voltage
Stab.	To prevent voltage hunting	Clockwise increases the damping effect
Stability selection	To optimise transient performance	See table
UFRO	To set Under Frequency Roll Off knee point	Clockwise reduces knee point frequency
UFRO select 50 / 60	To set UFRO control range	Switch position 5 = 50 Hz 6 = 60 Hz
Droop	To set voltage droop to 5% at 0 PF	Clockwise increases the droop
Trim	To match AVR input to Accessory output	Clockwise increases AVR sensitivity
Dip	To adjust frequency related voltage dip	Clockwise increases the dip
Dwell	To set the rate of voltage recovery time	Clockwise lengthens the recovery time
Mode	To select AVR or hand control mode	8 = AVR control. 4 = Hand control
Ramp	To set the soft start voltage ramp time	Clockwise lengthens the ramp time
O / Ex (sealed)	To adjust over excitation trip level	Clockwise increases the trip level
O / V (sealed)	To set over voltage protection trip level	Clockwise increases the level
PWL (sealed)	To set the maximum excitation voltage limit	Clockwise increases the voltage limit
Hand (sealed)	For manual excitation control	Clockwise increases excitation

Overload detector continuously monitors the excitation voltage and provides signals to shutdown the AVR power output device and trip an optional circuit breaker if the threshold setting is exceeded.

The circuit breaker isolates power from the exciter and AVR power devices if sustained over-excitation occurs. An overload condition produces a latched fault requiring the generator to be stopped for reset

Over-voltage monitor continuously monitors the voltage at the AVR terminals and provides signals to shut down the AVR power output device and trip an optional circuit breaker.

The circuit breaker isolates power from the exciter and AVR power devices if sustained over-voltage occurs. A fixed one second timer is included in the circuit to prevent operation during transient over-voltages, which are normal after load removed. The generator must be stopped to reset an over voltage trip.

Voltage adjustment
The generator output voltage is set at the factory, but can be altered by careful adjustment of the volts control on the AVR board, or by the external hand trimmer if fitted.

WARNING!

DO NOT INCREASE THE VOLTAGE ABOVE THE RATED GENERATOR VOLTAGE. IF IN DOUBT, REFER TO THE RATING PLATE MOUNTED ON THE GENERATOR CASE.

If a replacement AVR has been fitted or re-setting of the VOLTS adjustment is required, proceed as follows:-

Before running generator, turn volts control fully anticlockwise.

Turn remote volts trimmer (if fitted) to midway position.

Turn stability control to midway position.

Connect a suitable voltmeter across line to neutral of the generator.

Start generator set, and run at a no-load condition at nominal frequency e.g. 50-53 Hz or 60-63 Hz.

If the red light emitting diode (LED) is permanently illuminated, refer to the under frequency roll off adjustment (UFRO).

If the LED is flashing then refer to Over Excitation and Over-Voltage protection adjustments.

Carefully turn the VOLTS control clockwise until rated voltage is reached.

If voltage instability is present at rated voltage, refer to the Stability adjustment, then re-adjust voltage if necessary.

Voltage adjustment is now complete.

Stability adjustment

The AVR includes a STABILITY or damping circuit to provide good steady state and transient performance of the generator.

A switch is provided to change the response of the stability circuit to suit different frame size generators and applications, (see stability table above).

The correct setting of the stability control can be found by running the generator at no load and slowly turning the stability control anti-clockwise until the generator voltage starts to become unstable.

The optimum or critically damped position is slightly clockwise from this point, (i.e. where the machine volts are stable but close to the unstable region).

Under Frequency Roll Off adjustment (UFRO)

The AVR incorporates an under speed protection circuit which gives a volts per Hertz characteristic when the generator speed falls below an adjustable threshold known as the knee point.

The red light emitting diode (LED) gives indication that the UFRO circuit is operating. Turning the UFRO control clockwise lowers the frequency setting of the knee point and extinguishes the LED.

For optimum setting, the LED should illuminate as the frequency falls below just below nominal, i.e.47-48 Hz on a 50 Hz system and 57-58 Hz on a 60 Hz system.

The UFRO adjustment is pre-set and sealed at the works and normally only requires the selection of 50 / 60 Hz using the selector switch.

If the LED is flashing, refer to Over Excitation and Over-Voltage protection adjustments.

Dip adjustment

The DIP adjustment allows the user to have some control over the amount of frequency related voltage dip upon the application of load.

This feature is mostly used when the generator is coupled to turbo charged engines with limited block load acceptance, and operates only when the speed is below the UFRO knee point, (LED illuminated).

The circuit works by increasing the volts per Hertz slope to give greater voltage roll off in proportion to falling speed.

With the DIP control fully anti-clockwise the generator voltage characteristics will follow the normal volts per Hertz line as the frequency falls below nominal.

Turning the DIP control more clockwise provides greater voltage roll off allowing easier engine recovery.

Dwell adjustment

The DWELL operates only when the speed has fallen below the knee point set by the UFRO adjustment. With the DWELL control turned fully anti-clockwise, there is no DWELL and the voltage recovery will follow the engine speed recovery. Turning the DWELL control clockwise, limits the maximum rate of change of voltage recovery as the engine speed recovers.

Droop adjustment

Generators intended for parallel operation are fitted with a quadrature droop CT which provides a correction signal for the AVR, allowing each generator to share reactive current. It is important to match the generator no-load voltages to less than 1 % of each other, to ensure good reactive load sharing.

The DROOP adjustment is normally pre-set in the works to give 5% voltage droop at zero power factor.

Clockwise increases the amount of CT signal injected into the AVR. The generator terminal voltage falls with lagging power factor and rises with leading power factor. With the control fully anti-clockwise there is no droop.

If the DROOP potentiometer needs to be reset for any reason, then the following procedure should be followed:-

Run the generator at 50% rated current at any power factor between 0.8 lagging and 1.0 (unity). Ensure that the generator rated current value used is the true rating without any de-rate factor. If in doubt, check with the factory.

Measure the AVR S1 S2 voltage. This should be between 0.2 - 1.9 volts ac.

Calculate the required position of the DROOP potentiometer (0 - 100%), where 0% = fully anti-clockwise and 100% = fully clockwise :-

$$\% \text{ position} = \frac{20}{\text{S1 S2 Voltage}}$$

If the result is greater than 100, then it suggests that the Droop CT ratio is incorrect.

Trim adjustment

An auxiliary input is provided to connect to accessories, (A1, A2) and is designed to accept DC signals up to +/- 5 volts. These terminals are usually used for connection to a power factor controller, if required.

The DC signals presented to this input adds to, or subtracts from the AVR sensing circuit, depending on polarity, and allows the accessory to have an influence on generator excitation.

The TRIM adjustment allows the user to determine or trim how much control the accessory has over the AVR.

With the TRIM control fully anti-clockwise the accessory has no control, clockwise gives maximum control.

Any signal connected to this input must be fully floating and earth free.

Over Voltage adjustment

The AVR includes protection circuitry to remove generator excitation in the event of an over-voltage on the AVR terminals. Separate terminals are provided for the overvoltage sensing circuit (E3, E4). The shut-down signal acts on the AVR power output device.

Provision is made for the optional connection of a miniature circuit breaker to break terminals K1, K2, which cuts off the excitation power directly. This provides extra protection in the event of a malfunction of the AVR power output device.

The trip coil on the circuit breaker connects to the AVR which provides a trip signal to energise the coil in the event of an over-voltage.

The over-voltage adjustment is set and sealed at the factory but can be reset on retrofit AVRs. Clockwise rotation of the O / V adjustment increases the voltage trip level. An over voltage trip condition is indicated by a flashing red LED (which also indicates over excitation trip). The generator must be stopped to reset an over voltage trip condition.

Over excitation adjustment

The adjustment is set and sealed in the works and should not be altered. The shut-down signal acts on the AVR power output device.

Provision is made for the optional connection of a miniature circuit breaker to break terminals K1, K2, which cuts off the excitation power directly. This provides extra protection in the event of a malfunction of the AVR power output device.

The trip coil on the circuit breaker connects to the AVR which provides a trip signal to energise the coil in the event of an over-excitation condition.

An over excitation condition is indicated by a flashing red LED (which also indicates over voltage trip). The generator must be stopped to reset an over excitation trip condition.

Ramp adjustment

The AVR includes a soft start or voltage ramp-up circuit to control the rate of voltage build up when the generator runs up to speed. This is normally pre-set and sealed to give a voltage ramp-up time of approximately 3 seconds. If required, this can be adjusted between the limits defined in the specification.

Sometimes this feature is useful for starting large motors or energising large transformers. The technique is to run the generator up to speed with AVR terminals K1 K2 operated by a normally open relay (240v dc 10A rating). When the relay is closed, the voltage will build up smoothly over time, keeping the load surge currents to a minimum.

PWL

This adjustment controls the Pulse Width Limit of the AVR power output device and controls the maximum excitation that the AVR can deliver. This is pre-set to deliver the required short circuit current for the generator and should not be altered.

Mode and Hand

These controls are for service engineers use only and should not be tampered with. They allow the excitation to be controlled manually.

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