

Broadcasting Towers Operation

WEEK 8 – AVR and ATS

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Objectives

At the end of the topic students will be able to:

1. Understand the basics of AVR and ATS.
 2. Explain the working principle of AVR and ATS.
 3. Explain the applications of AVR and ATS.
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8.0 General information

- An Automatic Voltage Regulator (AVR) is an essential device used in electrical engineering to maintain a constant voltage level in electrical systems.
- By regulating the voltage output, AVRs ensure that electrical equipment operates efficiently and safely, protecting them from voltage fluctuations that can cause damage or inefficiencies.
- Automatic voltage regulators (AVR) are used to maintain a stable voltage on the load side of the power transformer under varying network load conditions.

(Understanding Automatic Voltage Regulators: Functions and Benefits, Emily Johnson, Electrical Technology Publications, 2023.)

8.0 General information cont'd

- Changes in load on electric power systems are always unavoidable. But the increase in load that is not accompanied by additional capacity will cause the system to operate abnormally.
 - The normal or abnormal condition of the power system leads to electrical voltage problems. Excessive reactive power can damage the generator stator windings due to increased stator currents.
 - Increased stator current can be overcome by increasing the generator voltage.
 - For this incident to not occur, an AVR can be used to adjust the generator voltage according to the increase in reactive power.
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8.0 General information cont'd

- A transfer switch is an electrical switch that reconnects electric power source from its primary source to a standby source. Switches may be manually or automatically operated.
 - An Automatic Transfer Switch (ATS) is often installed where a backup generator is located, so that the generator may provide temporary electrical power if the utility source fails.
 - An ATS not only safely switches-in the backup generator as a temporary source of electric power; it also commands the backup generator to start, based on certain conditions it continuously monitors on the primary feed.
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8.0 General information cont'd

- The transfer switch isolates the backup generator from the electric utility, when the generator is on and is providing temporary power. The control capability of a transfer switch may be manual only, or a combination of automatic and manual.
- The switch transition mode of a transfer switch may be Open Transition (OT) or Closed Transition (CT).
- When utility power returns for a set time, the transfer switch will transfer back to utility power and command the generator to turn off, after another specified amount of "cool down" time with no load on the generator.

(Automatic Transfer Switch (ATS) - TECO GROUP, Tecogroup, 2023.)

8.1 AVR components

- **Voltage sensing unit:** This component monitors the output voltage of the electrical system. It detects any deviations from the desired voltage level and provides feedback to the control circuit.
 - **Control circuit:** The control circuit processes the voltage information received from the sensing unit. It determines the necessary adjustments to the excitation system to correct voltage fluctuations. This circuit can be analog or digital, depending on the AVR design.
 - **Excitation system:** The excitation system supplies the necessary current to the generator's rotor. It consists of a transformer and rectifier, which convert the AC voltage to DC, allowing for precise control of the generator's output voltage.
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8.1 AVR components cont'd

- **Output voltage regulator:** This component adjusts the excitation current based on the control circuit's signals, helping to stabilize the generator's output voltage. It can include additional feedback loops to enhance performance.
- **Protection circuitry:** AVRs often include protection mechanisms to prevent damage from over-voltage, under-voltage, or excessive current. This circuitry can trigger alarms or disconnect the load in case of faults.
- **User interface:** Many modern AVRs feature a user interface that allows operators to monitor performance, adjust settings, and view alerts. This can include displays, buttons, and communication ports for remote monitoring.

(Components of Automatic Voltage Regulators (AVR), Michael Anderson, Power Electronics Press, 2021.)

8.2 AVR key parts summarized

- Voltage Regulator IC: Controls the output voltage.
 - Capacitors: Smooth out voltage fluctuations.
 - Resistors: Limit current and divide voltage.
 - Diodes: Allow current to flow in one direction.
 - Inductors: Store energy in a magnetic field.
 - Transformers: Step up or step-down voltage levels.
 - Heat Sink: Dissipates heat generated by the IC.
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8.3 AVR function

- **Voltage regulation:** AVRs automatically adjust the voltage output to maintain a steady level, compensating for fluctuations in load demand or input voltage.
 - **Protection:** They protect connected devices from over or under voltage conditions, reducing the risk of equipment failure or damage.
 - **Improving efficiency:** By maintaining optimal voltage levels, AVRs help improve the overall efficiency of electrical systems, leading to energy savings and enhanced performance.
 - **Stabilizing power supply:** AVRs stabilize the power supply in various applications, from industrial machinery to household appliances, ensuring consistent performance.
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8.3 AVR function cont'd

- **Monitoring and feedback:** Many modern AVRs include monitoring features that provide real-time feedback on voltage levels, allowing for proactive maintenance and adjustments.

(Understanding Automatic Voltage Regulators: Functions and Benefits, Emily Johnson, Electrical Technology Publications, 2023.)

- To maintain the output voltage of a generator within a desired limit.
 - To provide protection against undesirable conditions like voltage spikes, surges, and overloading.
 - AVR are mostly placed at the output side of a transformer, at the output side of a generator and between the feeder and load to ensure voltage regulation is secured.
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8.4 AVR working principle

- It works on the principle of detection of errors. The output voltage of an AC generator obtained through a potential transformer and then it is rectified, filtered and compared with a reference.
 - The difference between the actual voltage and the reference voltage is known as the error voltage. This error voltage is amplified by an amplifier and then supplied to the main exciter or pilot exciter.
 - Thus, the amplified error signals control the excitation of the main or pilot exciter through a buck or a boost action (controls fluctuation of the voltage).
 - Exciter output control leads to the controls of the main alternator terminal voltage.
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8.4 AVR working principle cont'd

- AVRs are essential devices in electrical systems, designed to maintain a stable output voltage despite fluctuations in load or input voltage.
- The following provides a detailed working principle within its parts.

Voltage sensing

- The AVR continuously monitors the output voltage of the electrical system using a voltage sensing unit. This component measures the actual voltage and compares it to a predefined set point.

Feedback mechanism

- If the sensed voltage deviates from the desired level, the AVR initiates a feedback mechanism. This involves sending a signal to the control circuit that indicates whether the voltage is too high or too low.
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8.4 AVR working principle cont'd

Control circuit processing

- The control circuit, which can be analog or digital, processes the feedback received from the voltage sensing unit. It determines the necessary corrective actions to adjust the voltage output. The processing speed is critical for timely adjustments.

Excitation Control

- Based on the control circuit's analysis, the AVR adjusts the excitation current supplied to the generator's rotor. Increasing the excitation strengthens the magnetic field, which raises the output voltage, while decreasing the excitation reduces the voltage.
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8.4 AVR working principle cont'd

Regulation and stabilization

- The AVR continually regulates and stabilizes the voltage output by making rapid adjustments in response to changing load conditions or input voltage variations. This continuous operation ensures that connected devices receive a consistent voltage level.

Protection features

- AVRs include protection mechanisms to guard against over and under voltage conditions. If the output voltage exceeds or falls below predefined limits, the AVR can disconnect the load or trigger alarms to prevent damage.
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8.4 AVR working principle cont'd

User interaction and monitoring

- Many modern AVRs feature user interfaces that allow operators to monitor voltage levels and adjust settings. These interfaces provide real-time data, alerts, and diagnostics, enabling effective management of the electrical system.

(Working Principles of Automatic Voltage Regulators (AVR), Laura Mitchell, Power Management Publications, 2023.)

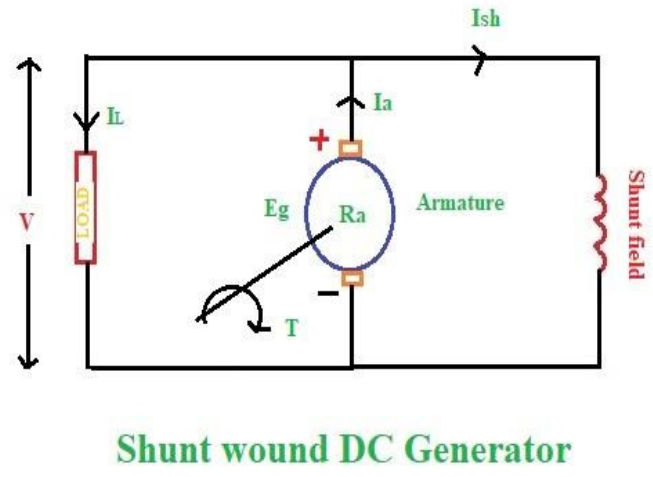
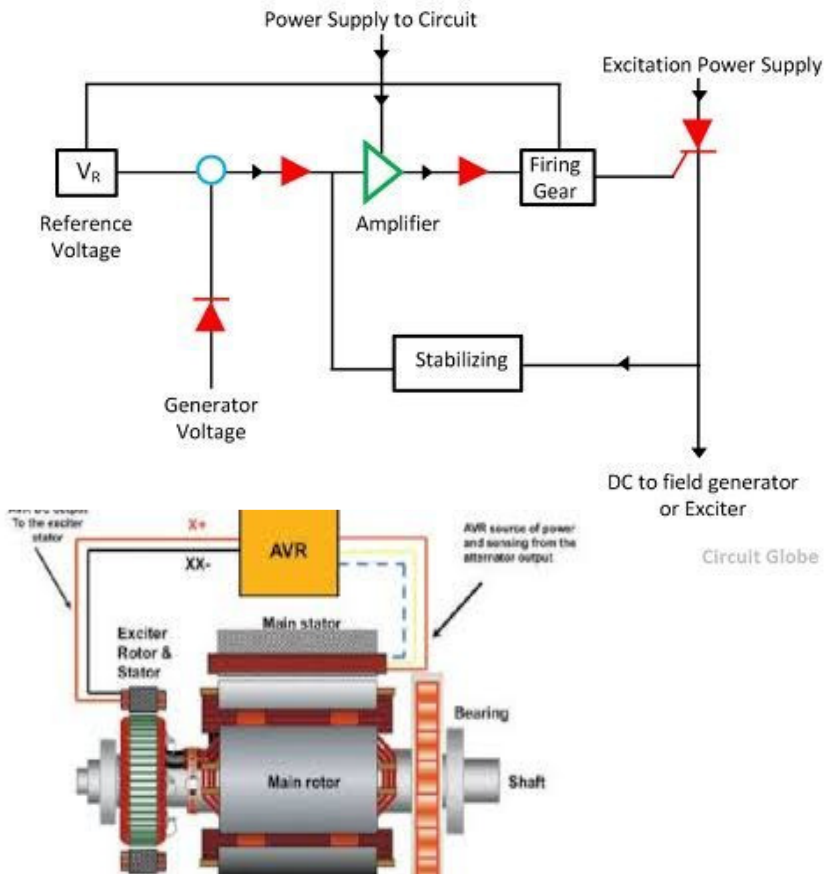
8.5 AVR Applications

- Voltage control and steady state stability: AVRs control the system voltage allowing the machine to operate nearer to steady-state stability.
 - Reactive load distribution: AVRs allow the distribution of reactive loads among the parallel alternators. It divides the reactive load between the alternators operating in parallel.
 - Overvoltage reduction: Such regulators reduce over-voltages caused by the sudden loss of load on the system.
 - Fault condition response: During fault clearance, AVRs increase system excitation to achieve high synchronizing power.
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8.5 AVR Applications cont'd

- Load change response: When there are sudden load changes, AVRs alter the excitation system quickly to keep the voltage stable under the new load circumstances. It increases the excitation of the system under fault conditions so that the maximum synchronizing power exists at the time of clearance of the fault.
 - This is done by changing the exciter output voltage and field current. But in the case of rapid fluctuations, standard ARVs may not respond quickly enough.
 - When there is a sudden change in load in the alternator, there should be a change in the excitation system to provide the same voltage under new load condition. This can be done by the help of the AVR with equipment operating in the exciter field and changes the exciter output voltage, and the field current.
 - Types of excitation system are DC excitation system and AC excitation system.
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8.5 AVR Applications cont'd

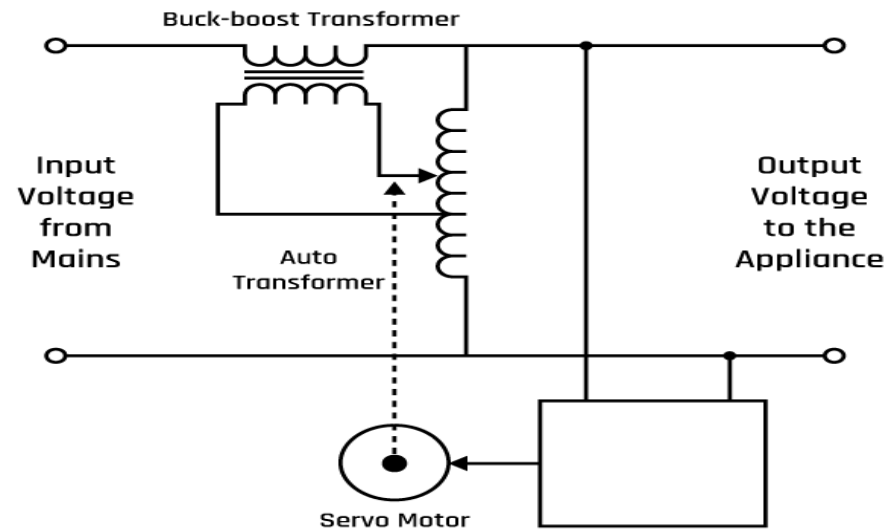


<https://www.midamericaengine.com/generator-excitation-control-systems-methods/>

8.6 Types of AVR

- **Servo (Linear /Rotary):** A servo voltage regulator provides stabilized voltage by changing the winding ratio of its transformer based on a negative feedback circuitry. It features a moving mechanism in the form of a servo motor and an attached carbon brush.

They are known for their high accuracy. The regulator is accurate up to $\pm 1\%$ for input voltage variations of up to $\pm 50\%$. They are also reliable and cost-efficient.



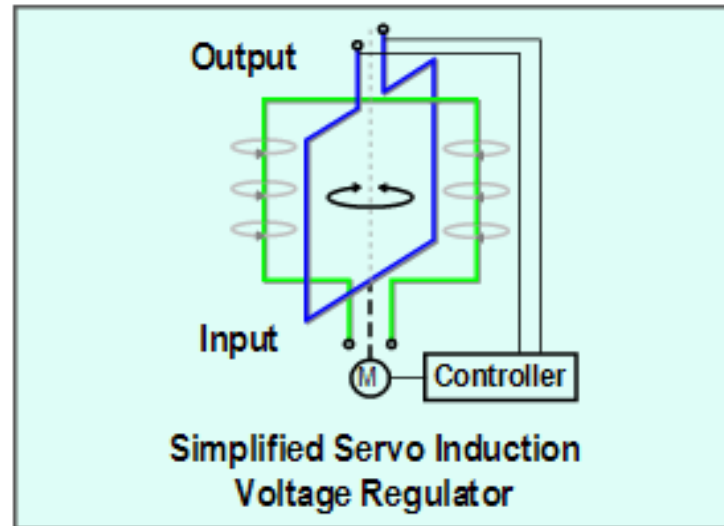
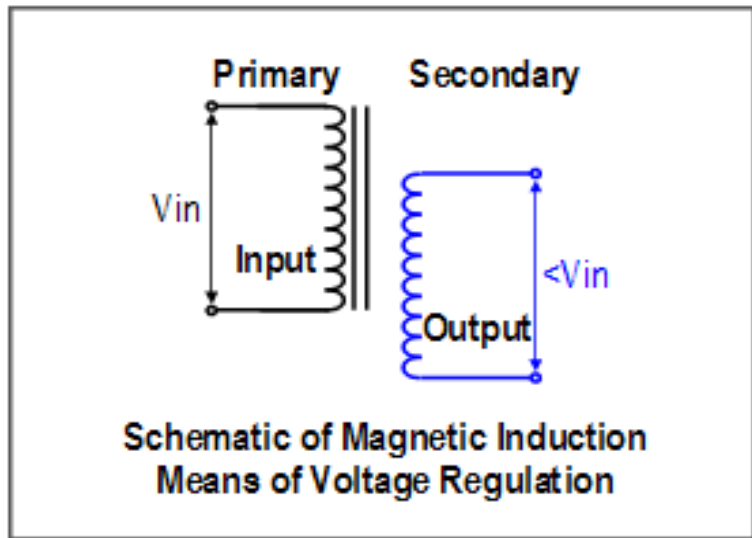
(<https://www.ashleyedison.com/2021/10/14/best-automatic-voltage-regulators/#>)

8.6 Types of AVR cont'd

- In a typical setup, a servo AVR is built with the following parts:
 - A buck-boost transformer, which is partly connected to the autotransformer to enable varying turns ratio.
 - An autotransformer or dimmer – a toroidal-shaped transformer with the fixed tap connected to the buck-boost transformer and the variable tap connected to the servo motor via a carbon brush.
 - Carbon brush – Serves as the moving mechanism that moves the auto-transformer according to the servo position.
 - Servo motor – Receives positioning signal from the control circuit and rotates its arm accordingly.
 - Control circuit – An electronic circuit of active and passive components like microcontroller, op-amps, and logic ICs. It samples the output voltage, calculates the adjustment needed and sends the respective offset signal to the motor.
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8.6 Types of AVR cont'd

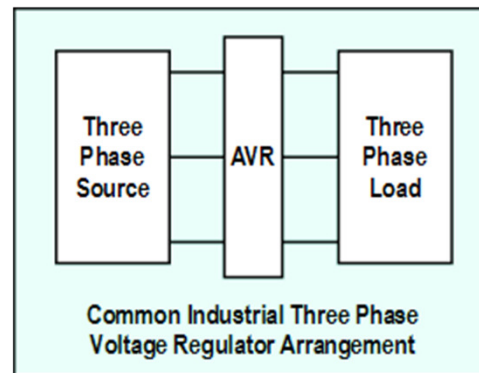
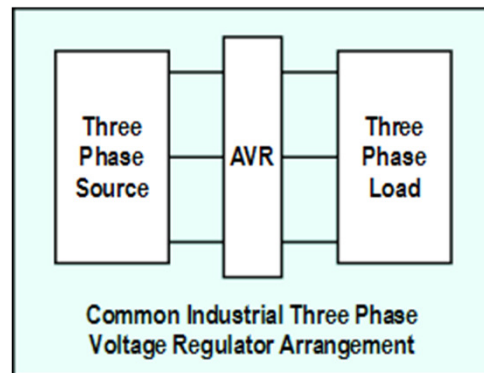
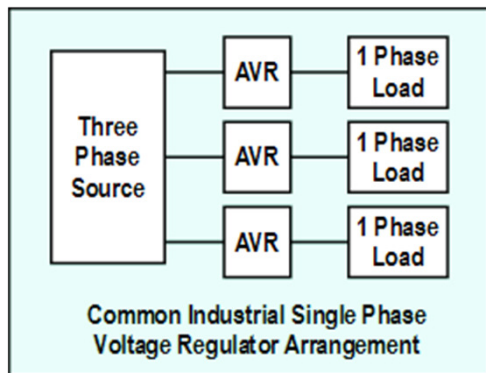
- **Magnetic induction:** low-maintenance AVR that operates reliably in harsh environments. The principle of the magnetic induction voltage regulator is to alter the proximity between the primary and secondary winding.



(<https://www.ashleyedison.com/2021/10/14/best-automatic-voltage-regulators/#>)

8.6 Types of AVR cont'd

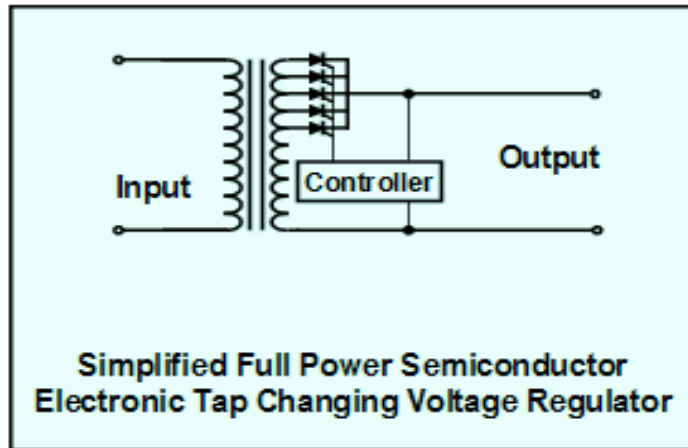
- A primary winding, which is wound multiple turns across the stator.
- A secondary winding wound across a movable shaft, or rotor.
- A servo that turns the rotor to a particular angle.
- Control circuitry, which samples and sends the appropriate output to the servo.
- Magnetic induction AVR is available for single and 3-phase AC voltages. For 3-phase applications, the regulator features 3 primary and secondary windings which are spaced 120 degrees apart.



[\(https://ustpower.com/comparing-automatic-voltage-regulation-technologies/function/phases-phase-regulation/\)](https://ustpower.com/comparing-automatic-voltage-regulation-technologies/function/phases-phase-regulation/)

8.6 Types of AVR cont'd

- **Static type (tap switching):** is fully electronic and has no moving parts though static tap regulators are also considerably cheap compared to its counterpart.



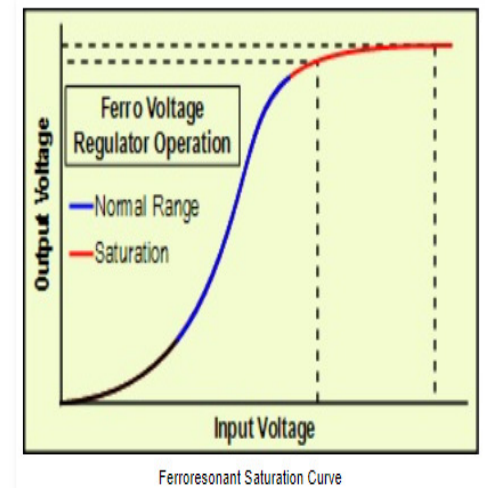
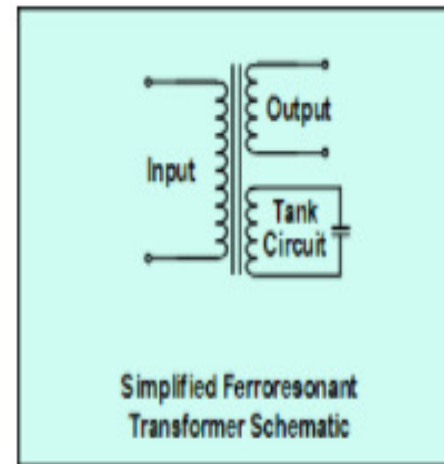
(<https://www.ashleyedison.com/2021/10/14/best-automatic-voltage-regulators/#>)

- A tap switching regulator has the following components:
 - A multitap transformer.
 - An array of SCR connected in series to each of the taps.
 - A controller circuit for activating the SCR based on the sampled output voltage.
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8.6 Types of AVR cont'd

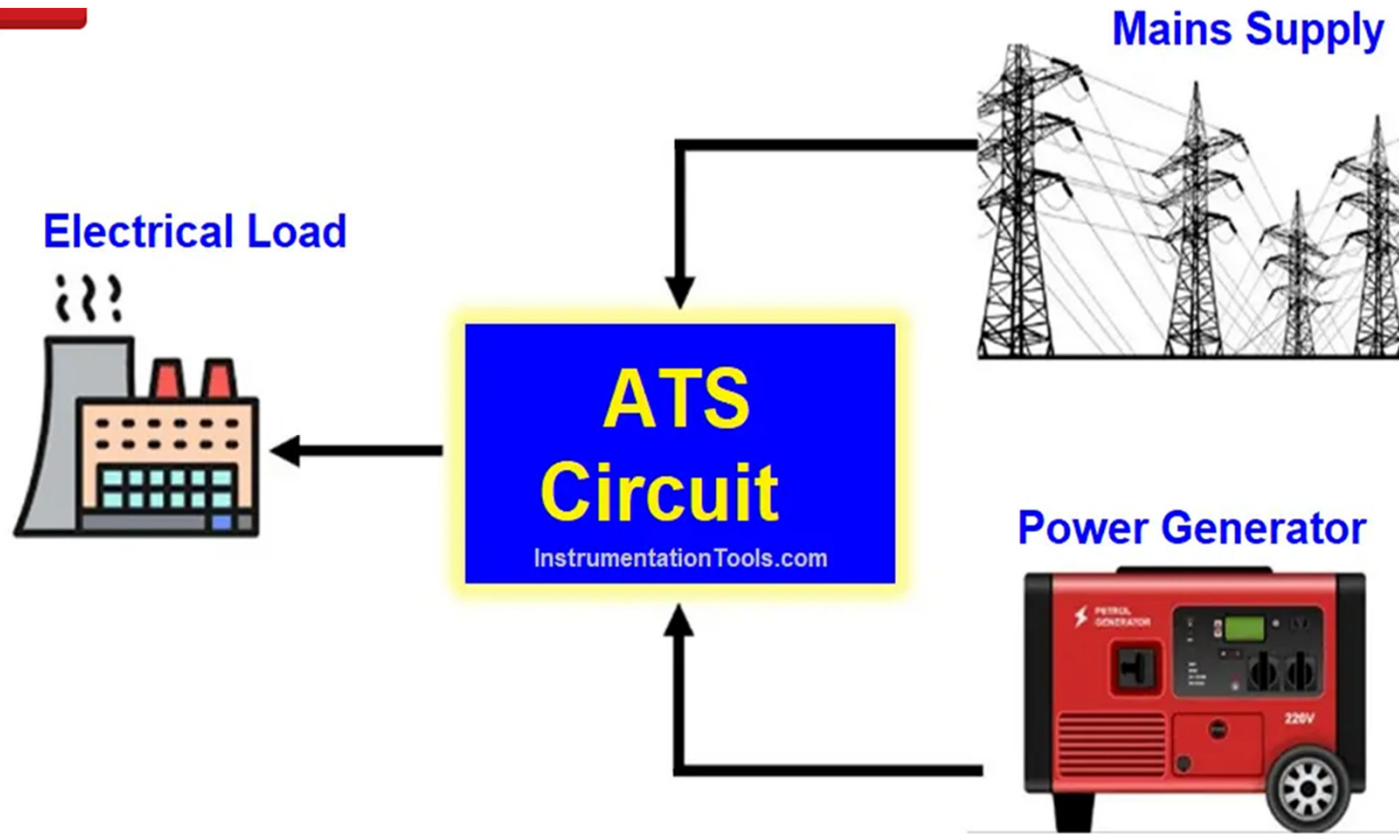
- **Solid state (ferro-resonant):** Ferro-resonant regulator, also known as ferro or constant voltage transformer (CVT), leverages an interesting principle of magnetic saturation to produce high-precise voltage regulation.

A transformer operating in the normal range will produce output voltage proportionating to the input voltage. Ferro-resonant regulator, however, operates on the non-linear part of the curve, where the output voltage remains consistent despite huge changes in the input voltage. There are no sensing circuits, mechanical components or a feedback loop involved as ferros operate by magnetic flux saturation.



saturation. (<https://www.ashleyedison.com/2021/10/14/best-automatic-voltage-regulators/#>)

8.7 ATS



[\(https://instrumentationtools.com/automatic-transfer-switch-using-classic-control-circuit/\)](https://instrumentationtools.com/automatic-transfer-switch-using-classic-control-circuit/)

8.8 ATS components

The ATS panel consists of several important components such as:

- The main switches is used to connect or disconnect electricity from the main source.
 - Backup switches performs the same function with the backup source.
 - Safety switches serve as a barrier to prevent the backflow and the defend against equipment damage.
 - Logic controls regulate how the ATS panel operates and is monitored.
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8.9 ATS working principle

- An ATS is a critical component in electrical systems, especially in applications involving backup power sources such as generators. Its primary function is to automatically switch the load between the utility power and a backup source when a power interruption occurs.
 - It monitors utility power supply by checking parameters such as voltage, frequency, and phase. If the utility power falls below a preset threshold (due to outages, fluctuations, or failures), the ATS initiates the transfer process.
 - It starts the back up generator after detecting a loss of utility power, the ATS sends a start signal to the backup generator. The delay associated with this process can be programmed to allow for short outages to pass without switching (commonly known as "start delay").
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8.9 ATS working principle cont'd

- It initiates the transfer of load once the generator reaches a stable operating condition, the ATS disconnects the load from the utility and connects it to the generator. This process is typically managed through mechanical or electrical switching mechanisms.
 - It monitors generator output and performance, ensuring it is supplying the correct voltage and frequency before transferring the load.
 - It restores the utility power when it is back and deemed stable, the ATS disconnects the load from the generator and reconnects it to the utility supply.
 - Another similar switching process is done to ensure stability and safety.
 - Lastly, many ATS units are equipped with self-testing capabilities to ensure reliability. They can perform regular tests without interrupting the power supply to connected loads. (Automatic Transfer Switch: Principles and Applications, John Doe, Electrical Engineering Press, 2022.)
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8.10 Applications of ATS

ATS are widely used in various sectors to ensure reliable power supply.

- **Emergency power supply:** ATS units are essential in hospitals, data centers, and emergency services where uninterrupted power is critical. They automatically switch to backup generators during outages, ensuring that vital operations continue without interruption.
 - **Industrial settings:** In manufacturing and industrial plants, ATS systems provide a reliable power supply to keep machinery and processes running. They help prevent costly downtime and protect equipment from damage during power fluctuations.
 - **Commercial buildings:** Many commercial establishments, such as shopping malls and office buildings, use ATS to maintain power for essential services, including lighting, HVAC systems, and security systems.
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8.10 Applications of ATS cont'd

- **Telecommunications:** In the telecommunications sector, ATS units ensure that communication networks remain operational during power failures, safeguarding critical communication infrastructure.
- **Renewable energy integration:** ATS can be integrated with renewable energy sources, such as solar and wind systems, to provide seamless transitions between grid power and generated power, enhancing the reliability of energy supply.
- **Residential applications:** Homeowners increasingly use ATS in conjunction with backup generators to ensure that essential home functions, such as heating, cooling, and refrigeration, continue during outages

(Applications of Automatic Transfer Switches in Modern Power Systems, Jane Smith, Power Systems Publishing, 2022.)

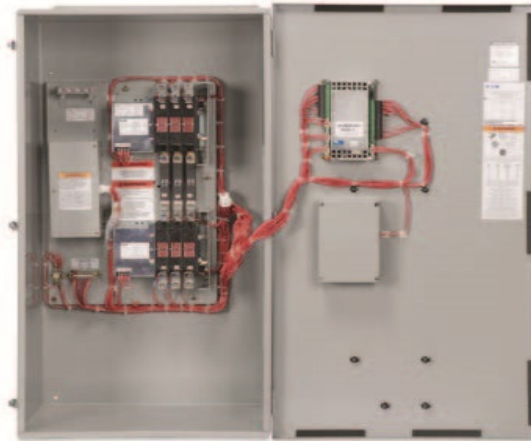
8.10 Types of ATS

- **Open transition** :These use a break-before-make system, meaning it will break contact with the previous power source (grid versus generator) before establishing new contact. This system creates a brief total loss of power, but a stable connection is reached within seconds.
 - **Closed transition**: These operate on essentially the same principles of an open-transition system, but the switch will maintain contact with both power sources (grid and generator) until a stable connection is established. Connection is held usually for roughly a tenth of a second, so there's no real danger of back-feeding or harmful overlap.
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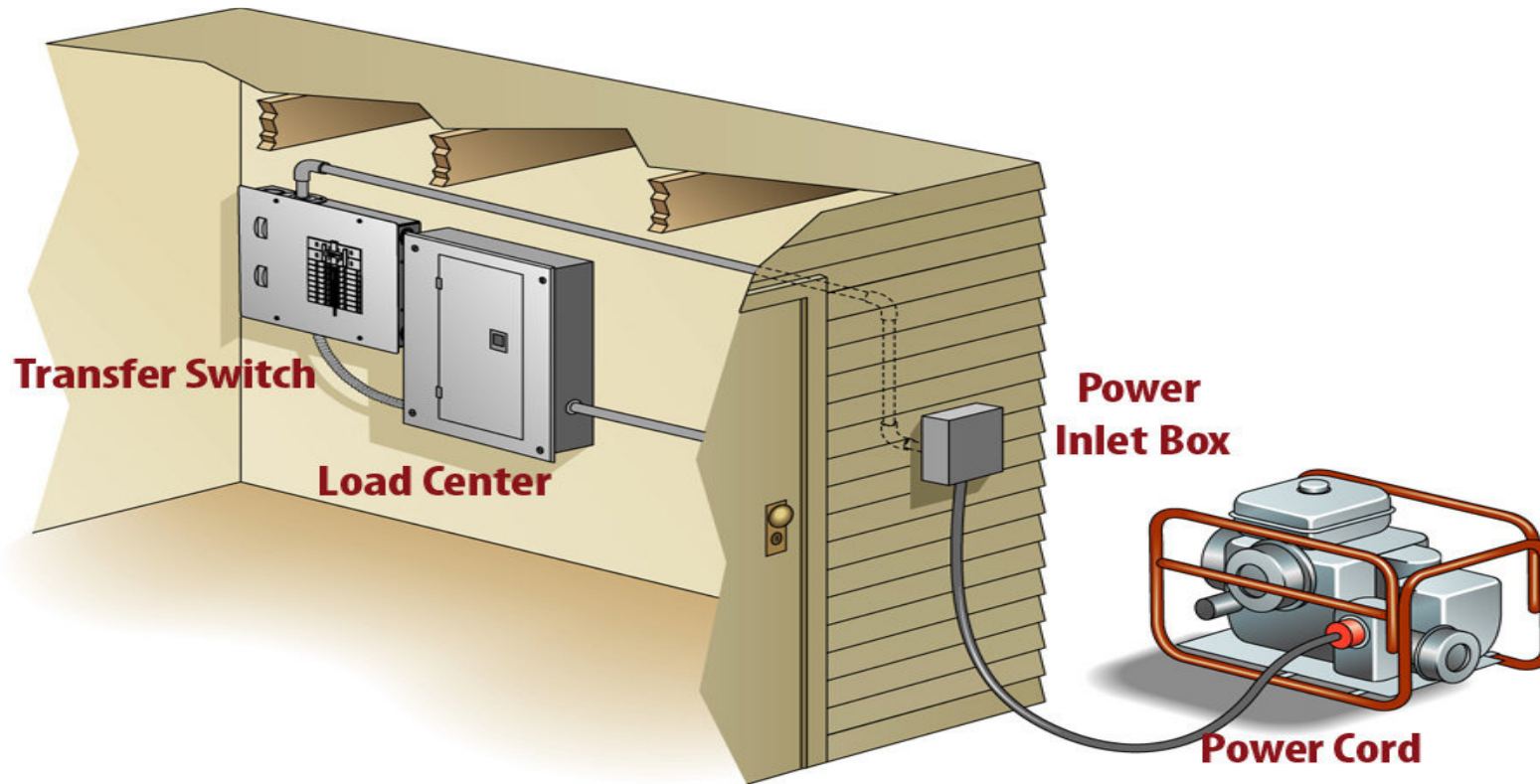
8.10 Types of ATS cont'd

- **Delayed transition:** With these ATS systems, a break-before-make is still established, but there's an engineered and purposeful delay before the switch from grid to generator power is made (and vice-versa). This delay acts as a fail-safe against power surges that can be common to heavy industrial equipment when powered on and off within seconds.

(<https://www.psicontrolsolutions.com/blog/types-automatic-transfer-switches/#>)



8.11 ATS installation



[\(https://blog.norwall.com/generator-information/planning-manual-transfer-switch-installation-materials/\)](https://blog.norwall.com/generator-information/planning-manual-transfer-switch-installation-materials/)

Summary

- AVR systems are essential for maintaining consistent voltage levels in electrical systems. There are several types of AVRs, each designed for specific applications and environments.
 - The most common types include electromagnetic AVRs, which use magnetic components to regulate voltage, and solid-state AVRs, which rely on electronic circuits for faster and more reliable operation.
 - Electromagnetic AVRs are typically found in older generators and smaller systems, while solid-state versions are prevalent in modern applications due to their superior performance and efficiency.
 - Another classification of AVRs is based on their operational methods: "series" and "shunt" AVRs.
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Summary cont'd

- Series AVRs control voltage by varying the resistance in series with the load, making them suitable for applications requiring precise voltage regulation under varying load conditions.
 - Shunt AVRs, on the other hand, adjust the voltage by shunting excess current away from the load, providing a more straightforward solution for larger systems where precise regulation is less critical.
 - Understanding the different types of AVRs and their operational methods is crucial for selecting the right regulator for specific electrical systems and ensuring optimal performance.
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Summary cont'd

- ATS are critical components in electrical systems that ensure a seamless transition between power sources, typically between a primary utility supply and a backup generator. There are two main types of ATS: open transition and closed transition.
 - Open transition ATS are the most common, where the switch disconnects the primary source before connecting the backup source, which can create a brief power interruption. This type is simpler and more cost-effective, making it suitable for many residential and commercial applications.
 - Closed transition ATS, on the other hand, allow for a brief overlap of the two sources, ensuring no interruption in power supply. This is particularly valuable for sensitive equipment that cannot tolerate even a momentary loss of power.
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Summary cont'd

- Another way to classify ATS is by control methods: manual and automatic.
 - Manual ATS require human intervention to switch between power sources, which may be suitable for applications where automatic switching is not critical.
 - In contrast, automatic ATS are equipped with sensors and control systems that detect power outages and initiate the transfer process without human involvement. This automatic functionality is crucial in critical environments such as hospitals, data centers, and industrial facilities, where uninterrupted power is vital for safety and operational continuity.
 - Understanding these types and their functionalities helps in selecting the right ATS for specific needs and ensuring reliable power management.
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Thank you for your good attention
Q&A

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