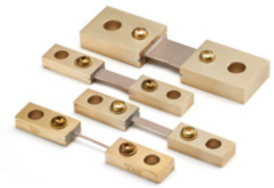
APPLICATION NOTE

Precision High Current Shunts Enable Renewable Energy Source Expansion

Riedon™ Panel Mount Ammeter Shunts by Bourns



Riedon™ Busbar Mount Ammeter Shunts by Bourns

Introduction

According to reports from both the International Energy Agency and the Energy Information Agency, the percentage of renewable energy sources used in the U.S. energy grid increased from 17 % to 21 % from 2018 to 2023. Renewable sources are expanding beyond traditional wind and solar to include battery energy storage systems to help maintain overnight and cloudy-day energy supplies. This growth in the use of multiple types of energy sources has led to the creation of a "hybrid grid." While a positive in ensuring a ready supply of power, a downside of this mix of energy sources is that it also brings new engineering challenges in the form of interfacing Direct Current (DC) power into an Alternating Current (AC) grid.

One common denominator amongst all power sources is current measurement. The need for precise current measurement is critical to maintaining an optimum state of charge in a battery system. It is also necessary to report current information for control systems so operators can make decisions regarding power delivery that could involve the engagement of additional sources. Because of the large scale of these power systems, traditional, highly reliable, low ohmic ammeter shunt resistors are seen by engineers as superior solutions to help them maximize grid performance.

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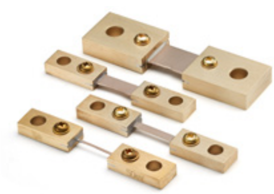

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The Nature of Renewable Power

Unlike established coal and natural gas power plants that use steam turbines to directly generate AC power, solar and wind generate power that is initially incompatible with national power grids. Solar power generated from photovoltaic panels is inherently DC and needs some form of inverter device to convert it to AC for connection to the grid. Many wind turbines, especially smaller units deployed in generating electricity for domestic, agricultural, and industrial premises, typically generate virtually unregulated AC. In this unregulated AC the frequency and voltage are not at a fixed value, thereby rendering this source of power incompatible with power grid infrastructure.

Larger wind turbines found on commercial wind farms also suffer from this same inadequacy. The reason: voltage and frequency are determined by the rotational speed of the turbine, which correlates with wind speed. Gearboxes have been used to increase the rotational speed to overcome this problem, but they are heavy and expensive. To overcome this, "direct drive" generators are an alternative low-cost and lighter-weight solution. Incorporating AC/DC and DC/AC power conversion rectification and inverter techniques using power semiconductor devices helps direct drive generators to efficiently interface with the grid at an acceptable voltage and frequency.

Consequently, the DC nature of renewable sources, particularly in distributed systems, demands the means to measure DC as well as AC power. Unfortunately, this rules out current transformers, which are extensively used for AC power measurement and provide the benefit of galvanic isolation from the circuit being measured. However, instruments based on Hall-effect current transducers can measure DC as well as AC. These also provide galvanic isolation, but often lack the required measurement accuracy of 0.1 % or less. This is where, although they require a separate means of isolation, current sensing techniques using precision ammeter shunt resistors come into play.

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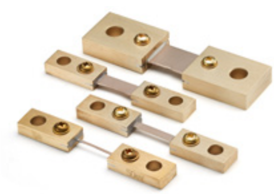

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The Basics of Ammeter Shunt Resistors

Engineers or designers who have studied electrical engineering will have come across ammeter shunt resistors. The principle of an ammeter shunt involves the insertion of a very low resistance in series with the load. With a voltage applied to the circuit, current passing through to the load will result in a voltage drop across the shunt resistor. With a suitable voltmeter, voltage measurements across the shunt enable the level of current to be determined by the simple application of Ohm's Law. In doing so, the meter's scale can be directly calibrated in Amps.

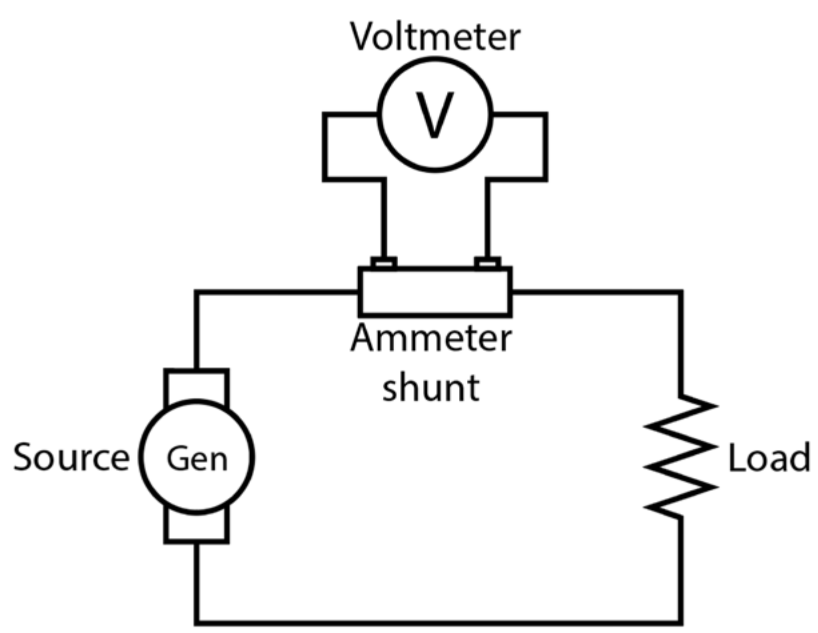

Figure 1. | *Conventional ammeter shunt circuit configuration*

Naturally, there is a bit more to ammeter shunts than this. It is important to note that shunt resistors are designed to work with voltmeters to provide a full-scale deflection at the shunt's maximum rated current, usually with standardized voltage drops of 50, 75 or 100 mV. Consequently, ammeter shunts will have a range of resistance values based on their maximum rated current and voltage drop. For example, a shunt designed for 100 A operation and a 100 mV drop will have a resistance of just 1 mΩ. To achieve the necessary accuracy, resistance values need to be precise while also mitigating measurement errors. To achieve this, a four-terminal construction is used for high-current shunt resistors, which enables the separation of the load-current connections from the measurement terminals.

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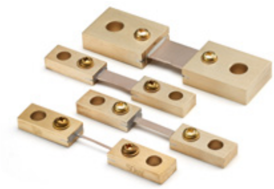

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The Basics of Ammeter Shunt Resistors (Continued)

Temperature is a key factor in determining the performance of shunt-based ammeter systems that aim to achieve 0.5, 0.25, and even 0.1 % accuracy. Resistance elements made from Manganin™ alloy combine precision with a very low Temperature Coefficient of Resistance (TCR). This allows operation over a typical temperature range from -40 °C to +60 °C. Also, despite their low resistance, shunt resistors carrying full load current can cause significant power dissipation. A suitable construction is required to aid heat dissipation (by conduction and convection) and, for continuous operation current, the device may require derating to comply with IEEE standards for DC instrument shunts.

Figure 2. | *The substantial four-terminal construction of typical high-current shunt resistors ensures accurate measurement and effective power dissipation*

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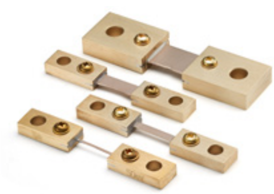

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Considerations when Selecting a Shunt Resistor

There are a number of important considerations when selecting an off-the-shelf shunt or specifying a custom-designed one for a shunt-based resistance measuring system. It is essential that resistance is constant with the variations in temperature experienced in the system. For optimum performance, the typical recommendation for designs is for the maximum temperature of the resistance element to be 80 ˚C, with a normal operating range of 40 to 60 ˚C. Temperatures above 80 ˚C will cause the resistance of the element to drift, with a resulting loss of current-measuring accuracy. The temperature of the element must not exceed 140 ˚C. Exceeding the maximum surface temperature of the shunt will cause an annealing process that results in a permanent change in the device's resistance. Care must be taken with the positioning and orientation of shunts to ensure these conditions are met. For example, it is highly recommended that resistance elements be mounted vertically to ensure the greatest air convection benefits. Heat sinks and/or forced-air or water-cooling may also be necessary, depending upon the application.

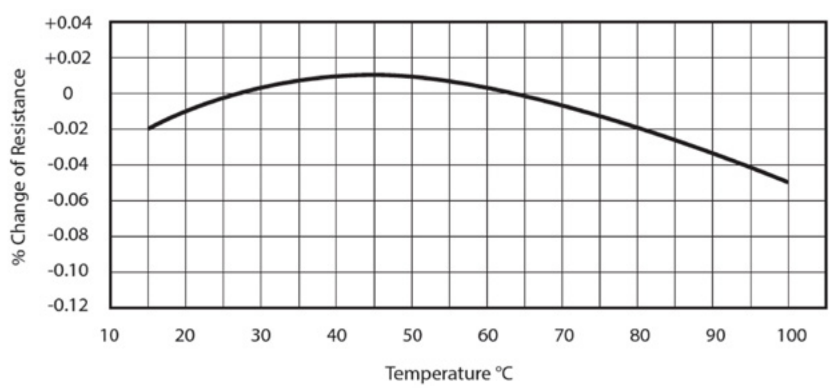

Figure 3. | *Manganin™ Temperature Coefficient of Resistance ± PPM/˚C*
Manganin™ alloy provides a low temperature coefficient of resistance

Additional care must be taken if the current being measured is in a high voltage system, as potential voltage at the shunt will also be present in the connecting leads and the reading instrument. Wherever possible, the shunt should be located in the grounded leg. This is essential in systems operating at 750 V and above. Usually, shunts are selected or designed to operate at a maximum continuous current of 2/3 of their rated current. However, a system for measuring intermittent or surge currents can tolerate a higher current without exceeding the above temperature constraints. As a result, the duty cycle of the shunt will be a crucial factor in the selection process. The shunt's maximum duty cycle, ambient temperature, and surface temperature will determine the proper cooling techniques required.

Finally, depending on the precision and repeatability needed in the application, ammeter shunt resistors may need to be traceable to standards and will require a schedule of recalibration and recertification. This is commonly carried out annually.

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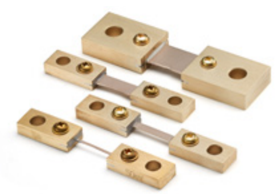

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Ammeter Shunt Resistors from Bourns

Bourns offers a full line of cost-effective, standard precision current DC ammeter shunts rated from 1 A through 3000 A that provide 50 mV and 100 mV outputs. For instance, the Riedon™ Model RS Series by Bourns features a standard voltage tolerance of ±0.25 % and a TCR of ±15 ppm/˚C. Bourns also offers custom-designed shunts with ±0.1 % voltage tolerances, alternative output voltages, and a full range of other options engineers can select from to suit a specific application's requirements.

Whether the application is industrial or required for today's emerging, renewable energy sectors, this application note has provided the important considerations designers need to make when selecting an ammeter shunt resistor or specifying a tailored standard product or a fully customized part. By selecting a well-established and experienced manufacturer of shunt resistors, engineers will realize the process is considerably simplified.

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