

Paralleling Generating Sets And Systems

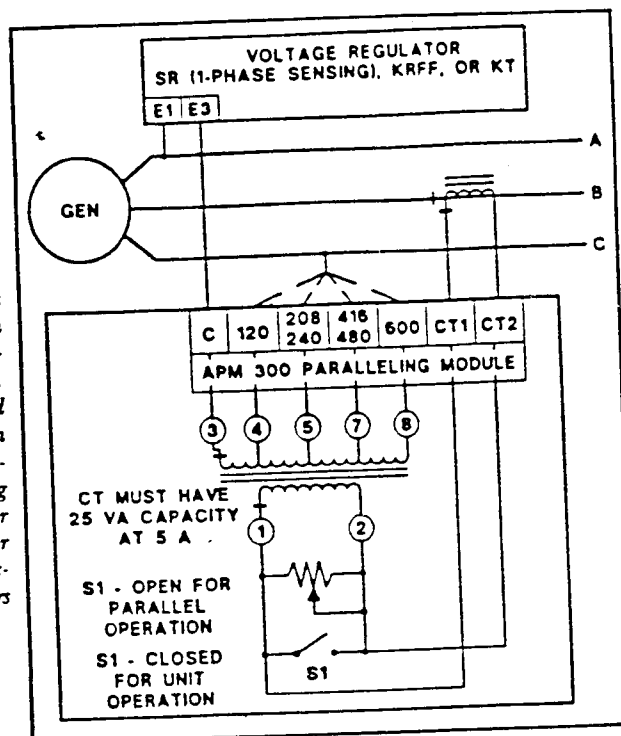
Editor's Note: During Basler Electric's 25th Annual Power Control and Protection Conference, in St. Louis, Mo., one subject stood out as being not fully understood and a source of possible confusion in the power generation industry. A great deal of instruction and discussion was devoted to Paralleling and Synchronizing of Power Generating Sets and Systems. Because of the complexity of the subject, space does not allow presenting it as comprehensively as it should be. Thus, the subject will be separated into two major components, Paralleling of Generating Sets and Systems this month, and Synchronizing of Generating Sets and Systems in the May 1991 issue. For more detailed information on either subject, contact the Marketing Department, Basler Electric, Box 269, Route 143, Highland, Ill. 62249 U.S.A.

When generators are connected in parallel, a parallel compensation circuit is required to assist the voltage regulators in controlling the generator reactive loads and to achieve balance between generators. This circuit will cause the voltage regulator to increase or decrease field excitation of the generator with the lower or higher field excitation, respectively. By controlling reactive loads, the parallel compensation circuit can eliminate undesired circulating currents.

Reactive Droop Compensation and Reactive Differential Compensation

Of the two forms of parallel compensation circuits, the most often used

Typical parallel droop circuit is made up of a current transformer and paralleling module. The paralleling module consists of a burden resistor and a switch connected across the primary of a transformer. The voltage regulator and paralleling module (which includes the isolation transformer and paralleling switch) carry the Basler model designation. Basler also offers a complete selection of current transformers for system matching.



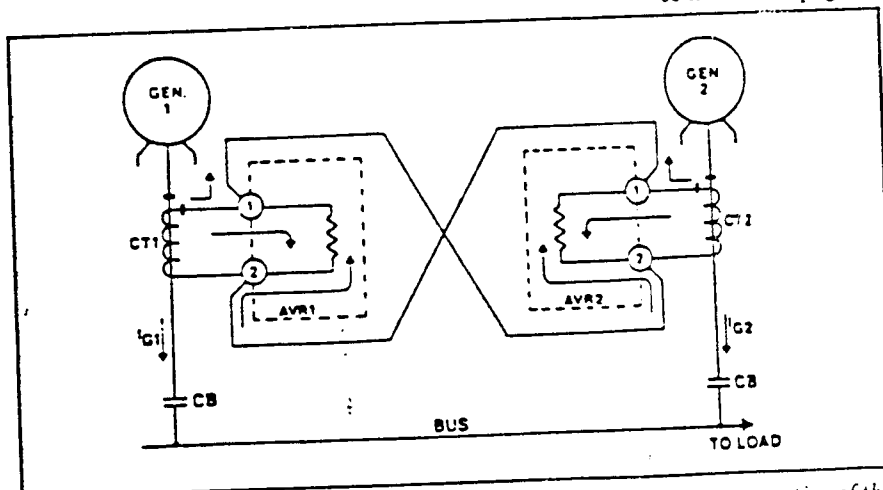
is parallel droop while the other is cross-current. Using the IEEE designation, these two types are termed "reactive droop" and "reactive differential compensation," respectively.

When reactive droop compensation is used, each parallel droop circuit is independent of the other. A typical parallel droop circuit is made up of a current transformer and paralleling module consisting of a transformer, burden resistor and a switch connected across the transformer primary which is the secondary of the current transformer. This switch shorts the secondary of the

current transformer and burden resistor the generator is to operate independently of the paralleling generating system.

The voltage across the burden resistor is vectorially added to the line voltage, producing an error signal to the voltage regulator. This voltage is also proportional in magnitude and has the same phase as the line current through the primary of the current transformer. When the load is at unit power factor, excitation will remain unchanged. By adjusting the system voltage when the load power factor is unity, the appropriate error

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Two generators paralleled with reactive differential compensation. Interconnection of the current transformers is shown. On generator number one, current transformer, CT1, terminal with the polarity mark is connected to the current transformer, CT2, on generator number two at the terminal with no polarity mark. On generator number two, current transformer, CT2, terminal with the polarity mark is connected to current transformer, CT1, on generator number one at the terminal with no polarity mark.

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signal can be produced.

The error signal, supplied to the voltage regulator, controls the excitation level of the generator. When the generators are paralleled, the regulator responds to this small increase in sensing voltage by reducing excitation to the generator field which will produce a droop in the generator output voltage. The amount a generator system will droop can be adjusted by the burden resistance and the current transformer ratio.

Most generators, paralleled with reactive droop compensation, are set to operate with maximum droop. The burden resistor is adjusted for maximum resistance or maximum voltage across the resistor to allow the most effective control of circulating currents. Setting the burden resistor for a system voltage droop of less than three percent may result in the regulator and paralleling circuit being unable to control circulating currents satisfactorily.

Voltage regulators with single-phase sensing provide approximately eight percent maximum droop while three phasing sensing regulators provide approximately six percent. When generators are paralleled, but have different type sensing, care must be taken to compensate for sensing differences using the adjustable burden resistor. When a lagging power factor load is increased, the bus voltage will droop by an increased amount. If a leading power factor load is increased, the bus voltage will increase.

In order to prevent the voltage from increasing or decreasing with the load power factor, another circuit interconnecting the current transformers of the individual regulators, can be used. Cross-current compensation (reactive differential compensation) allows operation in parallel without voltage droop caused by the error signal.

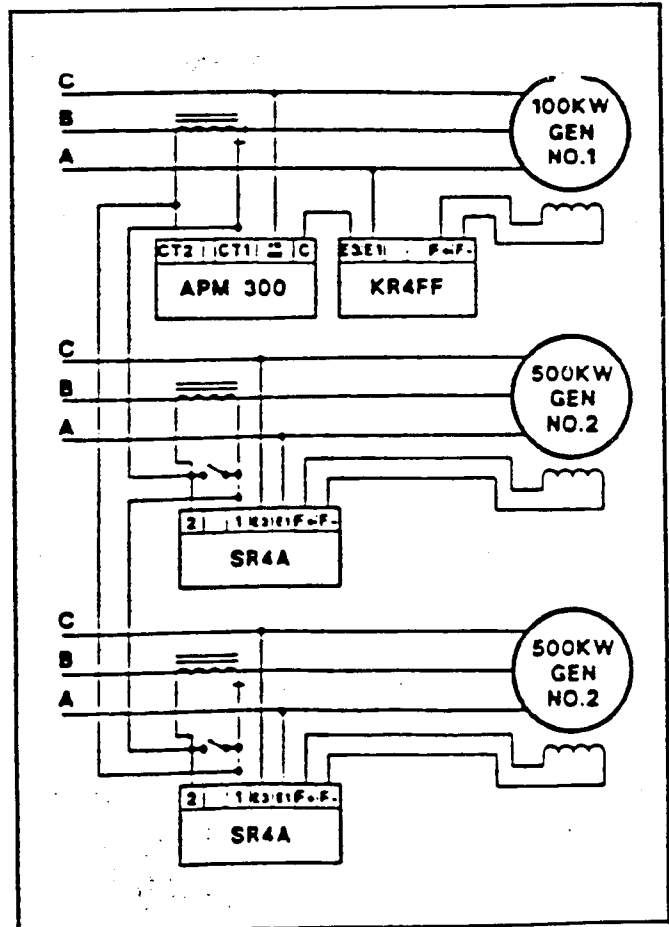
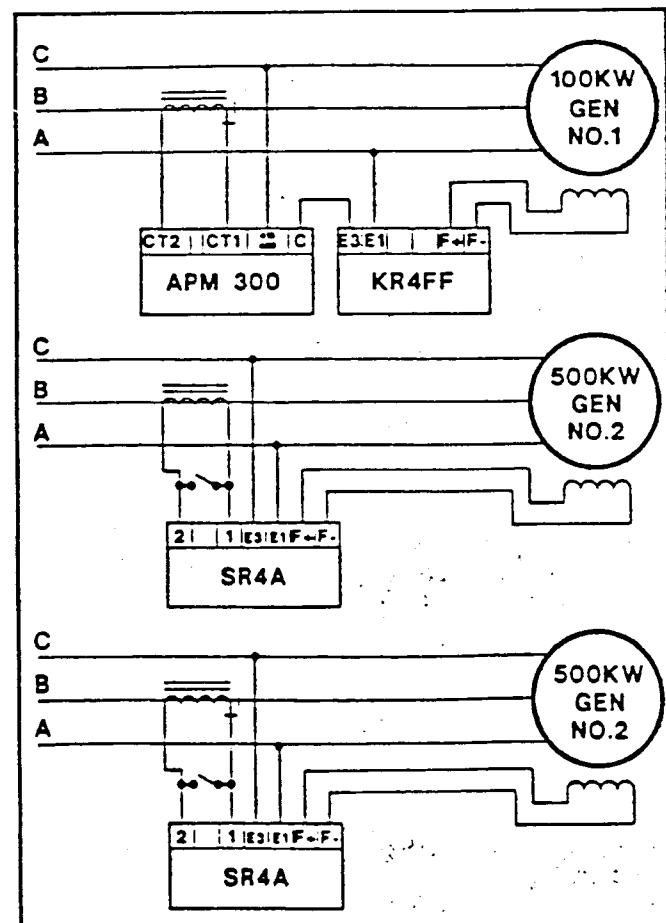
If one generator assumes more reactive load than the other, the line

and current transformer secondary current will increase, the voltage across the burden resistor will increase, the excitation will be reduced in that particular generator by the voltage regulator and the line current will decrease. An increase in current through the cross-current connect loop, caused by the imbalance of the first generator, will develop a voltage across the second generator's burden resistor opposite in polarity to the normal voltage of the second generator's current transformer. The opposite polarity will cause an increase in line voltage, causing the parallel generating system to balance itself out.

For the reactive differential compensation to perform properly, all current transformers must be connected into the cross-current loop. They must have the same ratios in order to properly cancel the voltage across the burden resistor. When different size generators are paralleled,

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When generators of different ratings are paralleled, current transformers of different ratios are used to step down the different line currents to a standard nominal secondary current. Droop operation is shown on the left, reactive differentiation compensation on the right. With reactive differential compensation, the burden resistor should be adjusted only a small amount to maintain proper control of circulating currents and to decrease the current imbalance of the current transformer loop. Basler voltage regulators and paralleling modules feature built-in isolation transformers for cross-current compensation.



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their current transformers must give approximately the same secondary current.

In addition to having compatible current transformer ratio, all generators must have the same burden resistor setting in order to balance the generator system's reactive load.

All generators must be tied into the cross-current loop for the system to perform properly. It is virtually impossible to parallel with an infinite bus (utility). If the cross-current connected system is paralleled with the utility outside the cross-current loop, a switch contact installed at any point in the loop may be opened, and all generators will operate in droop mode. For compliance with most safety codes, a ground connection is placed on the CT secondary. Only one ground can be installed on the loop.

Some means of isolation between the regulator sensing circuit and the current transformer circuit must be used with cross-current compensation. Basler regulators and paralleling circuits include isolation transformers to effectively isolate the cross-current loop from the input voltage circuit of the regulator.

The Current Transformer Unit-Parallel Switch

A switch, placed on the secondary of the current transformer to short circuit it and the burden resistor, will negate any signal to the generator. The switch in the "Unit" position allows the generator to operate independently of the parallel generating system without voltage droop.

If a unit-parallel switch is to be added externally to a paralleling circuit, leads to the shorting switch should be as short as possible.

Note: When operating with the reactive differential compensation circuit, the unit parallel switch should be an auxiliary contact on the main generator breaker. This contact should be closed and the CT secondary shorted when the main generator breaker is open.

Current Transformer Placement On Unmarked Phases

The current transformer can be connected to any phase of the generator as long as the system voltage is taken from the appropriate line voltage to maintain a 90 electrical

degree phase difference with the burden resistor voltage. If it cannot be determined which generator lines are phase A, B, and C, the paralleling current transformer should be placed on the generator phase that does not supply sensing voltage to the regulator. If the regulator is set-up with the generator for three-phase sensing, the current transformer must be placed on the B phase.

The polarity connection of the current transformer determines whether the generators are paralleled correctly if the phase rotation is undeterminable. If the current transformer is connected incorrectly, the generator voltage will not droop but will rise under inductive (lagging pf) load.

If cross-current compensation is applied, the cross-current connecting loop should be left open at one point until proper parallel operation is achieved with parallel droop compensation.

Current Transformer Selection

When generators of different kVA are paralleled, each current transformer used to parallel them should supply approximately the same secondary current. For best match, select a current transformer ratio that will provide the closest possible current to a typical 5A and 25 VA maximum burden transformer. Matching current transformer ratios with line

current to provide a nominal secondary current output is a detail that must not be overlooked.

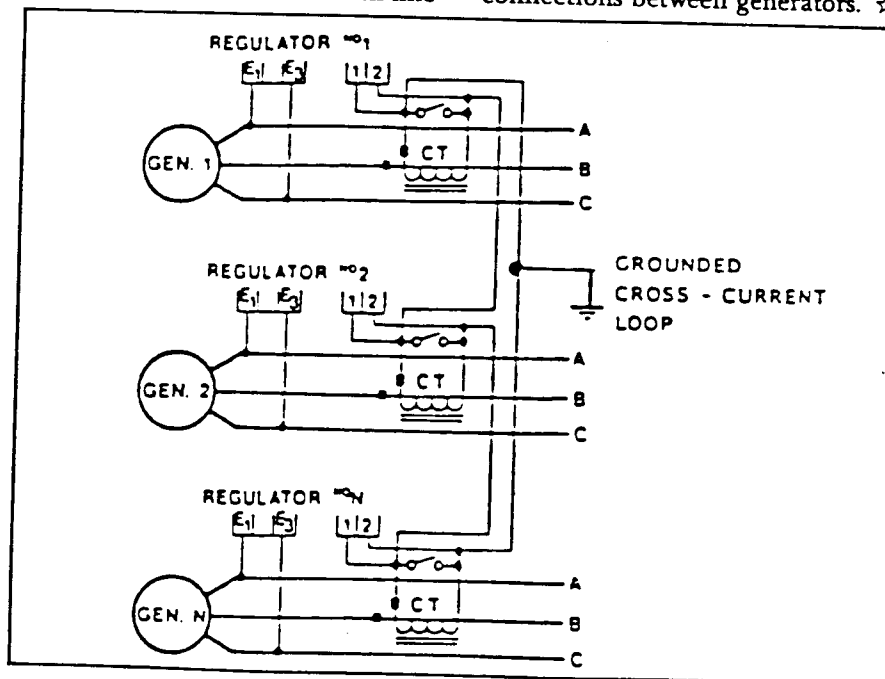
If the line current falls between the primary ratings of two current transformers, the current transformer with the higher primary current rating should be selected.

Paralleling Different Size Generators

For droop operation, the droop adjustment is used so that each generator droops a like amount at its rated load. Then, the generators can be paralleled and each generator can be adjusted to carry its proportional share of the reactive load.

For generators paralleled with reactive differential compensation, equal currents are needed to cancel opposite currents so that no droop in the generating system is present. This is accomplished by setting the burden resistors at maximum resistance and then adjusting the resistor across the current transformer with the smallest secondary current to a lower resistance.

Basler voltage regulators and paralleling modules feature a built-in isolation transformer for cross-current compensation. The isolation transformer is necessary to prevent the sensing circuit of the regulators from being paralleled by the cross-current connections between generators. ☆



Reactive differential compensation connection for paralleling generators. The cross-current loop must have all generators tied into the loop. If paralleling with the utility (infinite bus), which is nearly impossible with this connection, a switch contact installed at any point in the loop may be opened, and all generators will operate in droop mode. A ground connection (only one) is placed on the CT secondary.