Zone Control Design Goals

Primary goals were as follows:

(1) Make The System Practical And Flexible
(2) Save Money Through High Operating Efficiency
(3) Controls - Simple To Use
(4) Reduce The Number Of Heated Billets In The Reject Bin
(5) Develop A Better "Start Up" Mode
(6) Develop A True Billet "Hold" Mode
(7) Minimize Coils
(8) Reduce Floor Space

Zone Control Flexibility

There Zone Control approach of power supply configuration is to share a common DC section and have two or more separate inverter sections with corresponding heat stations and induction coils. The size of the DC section and each inverter section determines the available power at each individual coil and the method of operation dictates how these are sized. If the intent is to operate each inverter section at full capacity, then the total DC section is required to cover the required input power. An example would be two 750 kilowatt inverter sections that will be operated near 750 kilowatts. The DC section would be sized for the required kVA to output a total of 1500 kilowatts.

Is a 2000 Kilowatt, four Zone heater four 500 Kilowatt rated Zones? The answer is no, each zone can have a different capacity.

The above example, there is the DC section seized for 2000 kilowatts, and each inverter section rated as follows: Inverter 1, up to 1500 kW, Inverter 2, up to 750 kW, Inverter 3, up to 750 kW, Inverter 4, up to 750 kW. Total inverter connected is much higher than the DC section can supply, but this is to allow maximum flexibility in the operation of the system.

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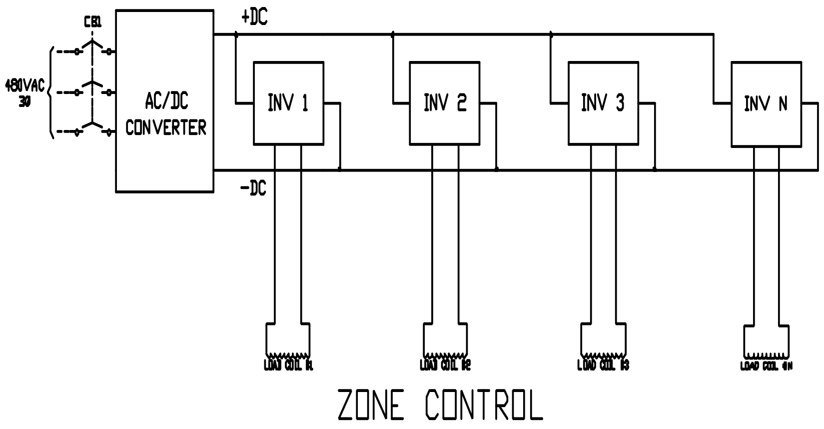

Typical Zone Control Configuration, DC Section – 2000 kilowatts, Inverter 1, up to 1500 kW, Inverter 2, up to 750 kW, Inverter 3, up to 750 kW, Inverter 4, up to 750 kW

Typically, with Zone Control the power distribution is 80 / 20 (or 80% on the first ½ of the line and 20% on the second half of the line. The ultimate in processing is offered with the Zone Control approach. Looking at the above example, if the process is optimized by supplying 1000 kilowatts in coil 1 and 600 kW in the second coil, then 250 kW in coil 3 and 150 kW in coil 4 (Total process requirements are 2000 of the available 2000 kilowatts.) An important note here is that the zones can be rated at different output frequencies to further enhance production and that Zones can be turned off when not required. The graph below shows the billet temperature with the Zone Control power supply and coil line system configuration at 80/20 Power Distribution.

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Same Rate, System only Requires Four Coils, Zone Control Power Supply
Billet Temperature Shown

The ultimate in processing efficiency is offered with the Zone Control approach. Looking at the above example, if the process is optimized by supplying 1000 kilowatts in coil 1 and 600 kW in the second coil, then 250 kW in coil 3 and 150 kW in coil 4 (Total process requirements are 2000 of the available 2000 kilowatts.) Another type of material or physical size may require a 70/30 approach, where 70% of the power is in the first half of the line and 30% in the second half of the coil line. Still another approach may require a soaking section and be configured at 1000 kW in the first zone, 500 kW in the second zone, 50 kW in the third zone and 300 kW in the fourth zone.

An important note here is that the zones can be rated at different output frequencies to further enhance production by offering more flexibility for an even greater range of product sizes and cross sectional configurations.
Zone control sections can be turned off when not required. If a smaller job is run on the system, the first zone, or first and second zone can be turned off completely. Any combination of active Zones can be operated.

Zones allow for individual coil control, power can be managed with high power distribution where required to obtain the required heating profile.

The advantages to the multiple output approach are; there is usually a reduction in floor space requirements, the utility interconnection requirements are to one point as opposed to a separate drop for each power supply required. One drawback would be that the system is somewhat specialized and not as easily repurposed for a different application. There are all points that must be considered during the specification of the system.

Zone Control Efficiency

Since each inverter section in a Zone Control system is an independently controlled portion of the overall line, how is it controlled? With the DC bus approach, the available power to the line of coils is distributed along the side of the inverter sections. This means that for a 2000 kilowatt DC rated section, there is 2000 kilowatts available on the DC Bus across all the inverters. Each individual inverter section draws from the "bulk" power available. Power is applied where it is the most efficient and necessary for the process. This allows for the most beneficial heating profile that can be achieved, which in turn uses the least amount of power for the induction heating process. A standard rule of thumb used to be to estimate the kilowatts required for a forging system was 5.5 pounds per kilowatt hour, therefore you could heat 11,000 pounds of steel to forging temperature with 11,000/5.5 = 2000 kilowatts. Zone control efficiencies have produced up to 7 pounds per kilowatt hour or up to 14,000 pounds on a 2000 kilowatt system. This is direct efficiency improvements on the utility cost to operate the system.

Additional savings realized with Zone Control

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- No output transformers
- No saturable reactors or switches
- Optimized heating profiles
- Minimized rejected heated billets thru hold mode and startup modes
- High input power factor

Zone Control Simple Controls

Electronic Control –

Zone Control systems utilize a PLC on each inverter which is tied into the main PLC. During a recipe recall, each zone power level is selected and the feedback is monitored. Further control can be zone through the use of infrared pyrometers looking through the coil windings into each zone coil for the expected temperature. The temperature data is analyzed against the program values and the algorithm makes the necessary output modifications to achieve the expected results. Many factors can influence the expected values against the actual values, factors such as incoming temperature of the billets; billets coming from outside on a 100 degree day, or a 20 degree day, or slight changes in the metallurgy from batch to batch are a couple such factors.

Start Up

Zone Control technology improves start up during production. This technology offers some major advantages over the conventional billet heating system. When a forging operation ceases operation for the day, the induction heater is turned off and the remaining billets cool down. Prior art was to either empty out the coils manually or through a start procedure that slowly heats the billets, however they are all heating from ambient and in a conventional system all the billets in each coil would be under the curie point drawing an equal amount of power. Systems with graded coils would draw more power on the front of the line, while the exit end would be lower. This leads to a lot of rejects prior to being able to forge the first billet of the day.

Zone Control allows for a the user to start a full coil line of cold material, keeping the billets stationary and bringing the billets up to temperature before starting production. Since each zone is controlled independently, the temperature gradient across the whole coil line is stair stepped with the exit end the hottest. This is representative of the actual heating during normal production and minimizes the billets lost as under temperature reject billets on start up.

Hold Mode

Usually with large billets or high power it takes a considerable amount of time to get the billets up to required temperature. Once this is achieved short stops are required in the forging operation, so as to not stop the induction heater. If the heater continues even in a slow mode correctly heated billets are rejected. The Zone technology is ideal for short stops in the forging production. If the operator needs to check anything with the forging equipment, which could include tool tightening, tool dressing or even the redirection of lubrication or just gauging a forged component to ensure everything is within specification,

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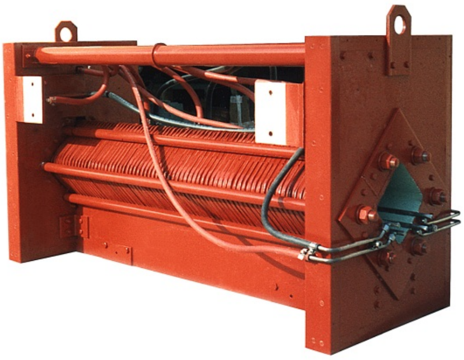
the induction billet heater can be place in a hold mode and the correct power is applied to each individual coil to maintain the temperature during this production stoppage. The advantage is that the system is not heating billets just to reject them. Using any of the proven billet emptying method which can be as simple as dummy billets, stainless steel tube or a completely automated emptying out system, each individual coil can be switched off. The column of billets can be forged during the empty out cycle, continuing production and maintaining a high efficiency, leaving the coil empty ready for the following shifts production.

Coils

The advantage with Zone Control technology is that each individual coil has the same electrical / mechanical design, meaning any coil can work in any coil position. Therefore, the customer only has to keep one individual coil module at any one given size as a spare instead of a complete coil line assembly.



Induction Coil for Round Cornered Square Billets

Floor Space

The floor space required against a traditional approach is reduced by 20% - 30% in most cases. This is due to the rapid heating done early in the coil line allowing for more time for conduction at elevated temperatures and a more uniformly heated billet upon exit.

Additional Advantages of Zone Control

Transistor Technology - IGBT Transistor technology is used for Zone Control. This offers higher electrical efficiencies over SCR/Conventional billet heaters. Using transistors in the inverters yields higher pounds per kilowatt as compared to SCR / Conventional systems. In addition, the input power factor is maintained near unity at all times.

Shuttle Systems - Every coil on the system can be placed in any location on the line. There are no unique coils, and therefore only one spare is required per set of coils. In addition, the system can be configured with

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a coil shuttle to minimize the amount of time required to change between coil sets. Due to the system configuration with the inverter sections directly below the induction coils, the bases are built with heavy duty aluminum tooling plate for coil mounting. This is suitable for the shuttle system to switch between sets of induction coils. Another feature of this automatic switchover is that the operator finishes a job and then switches the coils. The coil line switch to the other mounted set and can immediately start heating the new billet sizes. Even is the prior coil set still has hot billets in the coil change, the change can be made.

Four Zone Induction Heater with Coil Shuttle. Each Coil is Independently Controlled and there are Two Mounted Sets of Induction Coils for Coil Changeover by Selector Switch.

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Five Zone Induction System with Doors Open to Inverter Sections.
The Orange Boxes on the right hand doors hold the PLC Controls.

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