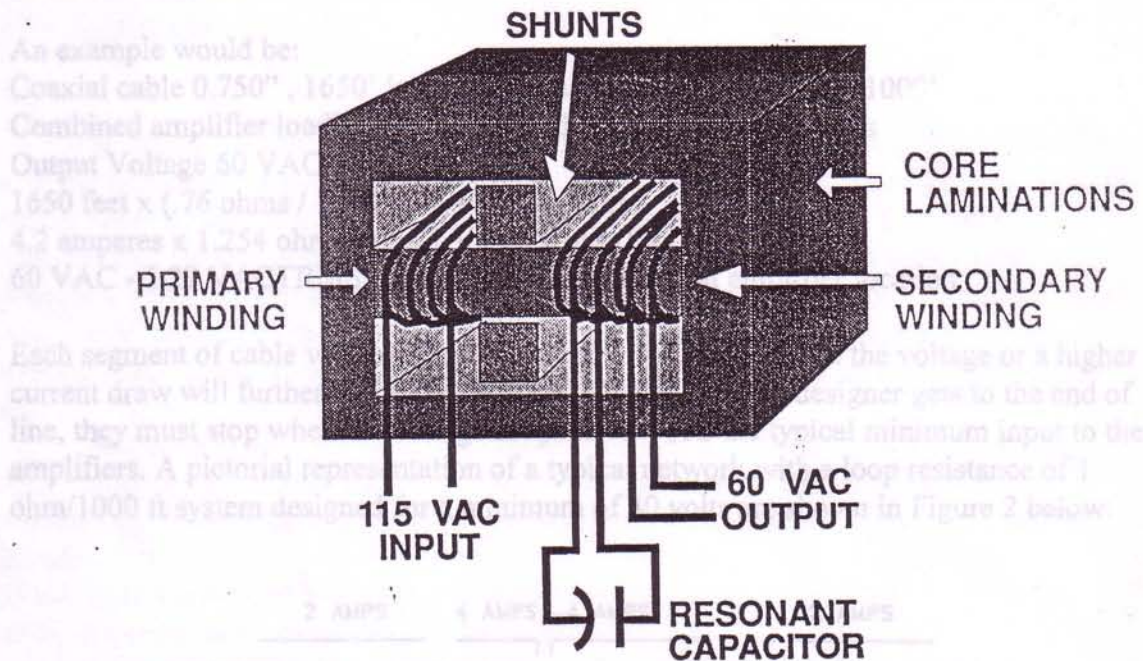


Design and Operational Considerations for HFC Network Powering

Hassan Kaveh, David Cushman, David Bibby

Ferroresonant transformers have been utilized in the CATV industry for many years. The inherent short-circuit protection that they provide protects both equipment and technicians from surges caused by accidental shorting of the cable center conductor to ground. A ferroresonant transformer is composed of two main components, a saturating transformer and a resonant capacitor. When voltage is applied to the main winding, the magnetic flux path becomes excited and sets up a resonance in the "tank circuit" or capacitor winding. The resonant capacitor and winding generate high currents that saturate the transformer and act as a "flywheel" which resists change. Once this has happened, any variations in the input line voltage will be resisted and provide for a wide range of input voltage. The load on the secondary is regulated by the use of shunts as shown in Fig. 1 below.



These shunts limit the magnetic path based on the air gap that is designed for the transformer. If the load on the secondary or output winding is increased, the resonance of the magnetic circulating paths decreases. To achieve load regulation, the effect of the shunts on the main magnetic path also decreases allowing more power from the primary to pass to the secondary. If a short is applied to the output, the transformer will "fold-back" or current limit because the resonant circuit will collapse similar to breaking the drive belt from the flywheel. Fold-back normally occurs at 125% of the rated load of the transformer. Most modern ferroresonant transformers have a higher fold-back current to allow them to operate into the highly capacitive loads in use in today's coaxial networks.

All power sources utilized in the communication corridor must be "inherently current limited as per the NESC (National Electrical Safety Code). Most municipalities adopt the NESC guidelines as an enforceable code. In addition to the power characteristics of the transformer, it also has good RF isolation characteristics separating the input from the output.

Why Use a Ferroresonant Transformer?

When a source of power is introduced into a coaxial cable, transmission losses are incurred based on the circuit resistance to the load. The RF amplifiers can draw from .3 amperes of current to as much as 1.75 amperes of current dependent on the design and function of the device. These amplifiers are distributed on the CATV coaxial network to distances of 3000'+ (914 meters +) in a branching configuration. Ohms law dictates that there will be voltage loss when a current passes through a resistance. In this example, the resistance is the coaxial cable between the power supply and the amplifier. Each amplifier has a power pack or module that converts the incoming 60-90 VAC to 24 VDC for use by the amplifier circuitry. The amplifiers combine to give the highest amount of current draw on the coaxial cable that connects the power supply with the nearest amplifier location.

An example would be:

Coaxial cable 0.750" , 1650' length 0.76 ohms loop resistance per 1000'

Combined amplifier loading or current on this segment 4.2 amperes

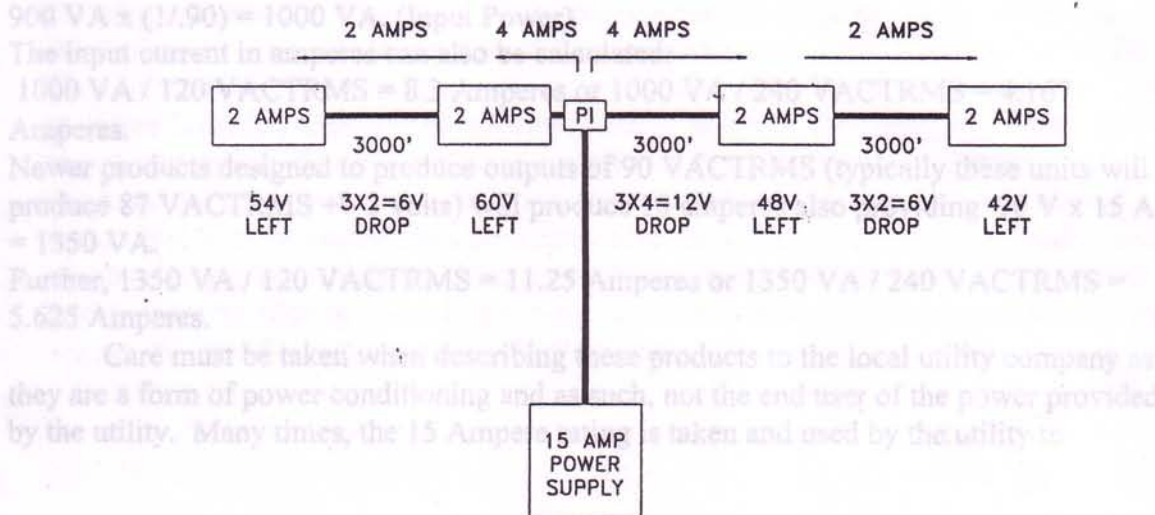
Output Voltage 60 VAC

$1650 \text{ feet} \times (.76 \text{ ohms} / 1000 \text{ feet}) = 1.254 \text{ ohms}$

$4.2 \text{ amperes} \times 1.254 \text{ ohms} = 5.27 \text{ VACTRMS (loss)}$

$60 \text{ VAC} - 5.27 \text{ VACTRMS} = 54.73 \text{ VACTRMS at that amplifier location}$

Each segment of cable with load passing on it will further reduce the voltage or a higher current draw will further reduce the voltage. By the time the designer gets to the end of line, they must stop when the voltage drops to 42 VAC the typical minimum input to the amplifiers. A pictorial representation of a typical network with a loop resistance of 1 ohm/1000 ft system designed for a minimum of 40 volts are shown in Figure 2 below:



If a standard transformer were to be used in this application, the output voltage of the transformer would follow the input voltage (2:1 transformer converting 120 VAC to 60 VAC). If the end of line were at 42 VAC and the input line dropped to 110 VAC, the resulting voltage at the end of line would be less than 37 VAC causing all the devices in this area to turn off. In addition, most of the power modules in the amplifiers today are switchmode regulators or "switching power supplies". These units are constant power meaning that they will draw higher amperage at lower voltages ($27 \text{ VA} / 60 \text{ VAC} = 0.45$ amperes or $27 \text{ VA} / 42 \text{ VAC} = 0.64$ amperes). If a voltage drop occurs, the amplifiers will draw more current which increases the voltage drop in the coaxial cable which in turn reduces the voltage available to the amplifier's power module which causes it to draw more current, and the cycle continues until the units at the end of line start switching off which reduces the current and allows the voltage to rise again. Hence, if a standard transformer were utilized, a momentary voltage drop could cause interruption of service to the customer.

A ferroresonant transformer will regulate its output voltage typically to within +/- 2% of its rated output voltage. This characteristic allows it to function typically from 90 VAC to 140 VAC. This prevents wide voltage fluctuations at the end of line of the CATV coaxial system.

Ferroresonant Efficiency

The efficiency of a ferroresonant transformer is limited to approximately 90-92% due to the utilization of power by the tank circuit. The transformer is designed to regulate a specific load or the most common amperage rating in use in CATV of 15 Amperes. Under-loading the transformer will cause a drop in efficiency since the tank circuit will still require about the same amount of power that it takes to regulate for 15 amperes. Due to this factor, most manufacturers provide units at varying amperage levels to reduce operating costs (kilowatt dollars) and initial investment costs (smaller transformers cost less).

The output power of a ferroresonant transformer is derived by multiplying the output voltage by the output amperage. A 60 VAC 15 ampere supply has a 900 VA output rating. If we follow the efficiency discussion above, the input power can be derived:

$$900 \text{ VA} \times (1/.90) = 1000 \text{ VA. (Input Power)}$$

The input current in amperes can also be calculated:

$$1000 \text{ VA} / 120 \text{ VACTRMS} = 8.3 \text{ Amperes or } 1000 \text{ VA} / 240 \text{ VACTRMS} = 4.167 \text{ Amperes.}$$

Newer products designed to produce outputs of 90 VACTRMS (typically these units will produce 87 VACTRMS +/- 3 volts) will produce 15 amperes also providing $90 \text{ V} \times 15 \text{ A} = 1350 \text{ VA}$.

$$\text{Further, } 1350 \text{ VA} / 120 \text{ VACTRMS} = 11.25 \text{ Amperes or } 1350 \text{ VA} / 240 \text{ VACTRMS} = 5.625 \text{ Amperes.}$$

Care must be taken when describing these products to the local utility company as they are a form of power conditioning and as such, not the end user of the power provided by the utility. Many times, the 15 Ampere rating is taken and used by the utility to

calculate the kilowatt load of un-metered power supplies. This creates a situation where the input power is calculated as:

$$120 \text{ VACTRMS} \times 15 \text{ ampere} = 1800 \text{ VA.}$$

This incorrect way of calculating the input draw is 800 VA higher than the power a fully loaded 15 ampere ferroresonant transformer could draw. However, the ferroresonant transformer is rarely deployed in a CATV system in a location that draws the full 15 ampere rating. The situation is usually caused by a lack of understanding of how a coaxial system uses power and how a ferroresonant transformer is rated and operates (see the attached letter for utility companies).

Typical Constructions

In use in the communication industry today are two types of ferroresonant transformers. These are the non-standby ferroresonant transformer and the common ferroresonant transformer. Battery back-up systems or UPS (un-interruptible power source or supply) power supplies can be of either type. A redundant system utilizes a separate ferroresonant transformer and inverter transformer. The common ferroresonant transformer design combines the winding from the inverter input side into the ferroresonant transformer input. Thus the inverter is "common" to the ferro. The redundant inverter transformer supplies its output directly to the line. A common ferro inverter supplies its output to the ferroresonant transformer. The redundant unit will typically run 2+hrs. on a set of three batteries while the common ferro inverter will run 1 ½ hrs. from the same set of three batteries. This difference in battery operation time is due to the losses incurred by passing through the ferroresonant transformer (90 % efficiency). An inverter circuit that is 85% efficient is applied to a ferro transformer that is 90% efficient. The resulting battery to output line efficiency is 76%.

Momentary Input Inrush Currents in Ferroresonant Transformers

When power is first applied to a ferroresonant transformer, there is an immediate inrush of current to energize the capacitor and tank circuit. This momentary condition can sometimes be 5 times greater than the operating current in common ferroresonant transformers and 2-3 times greater in ferroresonant transformers utilized in non-standby and redundant standby systems. This momentary current surge can cause circuit breakers installed on the input line to trip open if they are under rated or not classified to handle this type of inrush. While a 15 ampere ferro will draw only 8.3 amperes in normal operation under full load, this inrush characteristic demands the use of 20 ampere circuit breakers for the standard ferroresonant transformers and 20 ampere high magnetic or high inrush breakers for the common ferroresonant transformers. A high magnetic circuit breaker is similar in function to a slow blow fuse. It will allow a momentary high current condition to pass but trip open during a sustained over current condition. The common ferroresonant transformer has a larger mass core and thus has a higher inrush current that requires the use of a high magnetic circuit breaker.

Surge Protectors / Transient Voltage Protectors

The industry as a whole uses the incorrect term "Surge protector" to describe devices that are designed to stop momentary over-voltage situations. The correct term for these conditions is "Transient voltages". A surge protector is a device to open a circuit when there is an over current situation. Fuses and circuit breakers are examples of surge protectors. The devices in use in the CATV industry fall into two major classifications; Input protection and Output protection. The reason for this distinction is the fact that the power supply utilized in the CATV industry is "inherently current limited". This allows the utilization of devices that can actually become a short circuit when activated. The input side devices must react only to the voltages above their rated set point. MOVs or Metal Oxide Varistors are probably the most common input protection device. These devices have a high energy absorption capability but allow the voltage to continue to rise as they start to conduct in an over-voltage condition. This characteristic combined with the ferroresonant transformers capability to absorb limited voltage transients creates a superior combination to protect the network from voltage transients coming from the AC source. The output side devices fall into three categories: crowbar circuits, tranzorb diodes and gas discharge tubes (GDT).

Efficiency Calculation and operating Cost

Understanding the principle function of CATV power supplies and how they are rated for operation can be of benefit to both the CATV operator and the utility company. The power supply most commonly in use is a 15 Amp unit. The attached document supplies information on the power consumption of this unit. This model utilizes a ferroresonant transformer that is 90% efficient. The basic operation of this unit is to transform incoming utility AC to 60 VAC RMS to supply the line equipment. The ferroresonant transformer is used because of its regulation characteristics and ability to withstand shorts on the 60 Volt side for long durations. The efficiency figure is lower than a normal transformer due to the fact that some of the energy being applied to the transformer is utilized in a "tank" circuit that provides the regulation. Therefore, if the total output power [Volts x Amps or 60 x 15] is multiplied by the efficiency [1/0.90] the input power can be calculated.

$$(60 \text{ VAC} \times 15 \text{ Amp}) \times (1/0.90 \text{ Efficiency}) = 1000 \text{ Watts}$$

As the required load on the output side decreases, the energy to the tank circuit stays constant such that the efficiency of the transformer drops off. Because of this fact, Antec Power supplies of several output loading levels are designed to minimize the operating cost for the CATV operator. It is therefore recommended that, wherever possible the power supplies be utilized at full load.

In most cable systems, it is difficult to provide a system design that can utilize the power supply to it's full load rating. Such parameters as physical location of the power supply, allowances for RF line gear that is not fully loaded with optional modules, outdated design principles that de-rated the load to increase power supply life and the possibility of

future expansions to the cable system all combine to present an approximate real world loading of 75%.

When a customer requests recommendations on powering for use in determining utility billing, our first recommendation is to meter the power supplies. If this is not economically feasible our next suggestion is to sample 10% or more of the power locations with a phase factor correcting power meter on the input side. If this is not practical then the calculation listed above should be used with some factor of underloading being applied to the output load. $[((.75 \times 15) \times 60) \times (1/0.90) = 833 \text{ Watts}]$

The underloading factor can sometimes be determined by examining the systems "as built" powering maps, or by mutual agreement between the utility company and the engineers of the local system.

About the Authors:

Mr David L. Cushman is the staff application engineer at Antec Network Powering group. He can be contacted on Tel: + 1 (678) 473-2000 Fax: (678) 473-8182
Email: david.cushman@antec.com

Dr Hassan Kaveh is based in Sydney Australia and provides technical support for the Antec Network Power products in the Region. He can be contacted on Tel: (61-2) 9686 - 9444 Fax: (61-2) 9686 7113, E mail: hkaveh@s054.aone.net.au

Mr David Bibby is the application engineer for the South East Asia region. He is based in Philippine and can be contacted on Tel: +63 2 47 252 5036, Fax: +63 2 47 252 5037,
Email: david.bibby@antec.com