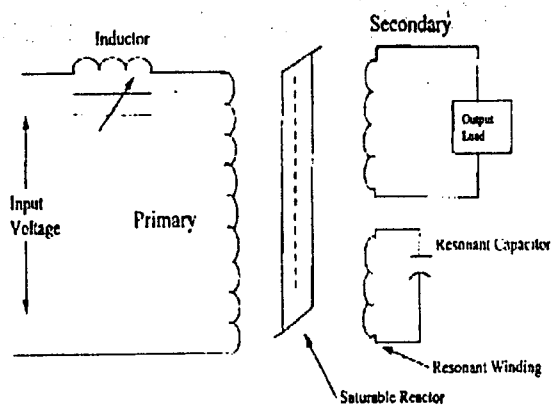# HFC Network Powering for the New Generation of Applications

H. Kaveh
ARRIS International
Sydney, Australia

G. Steenton
ARRIS International
Atlanta, GA, USA

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 he use of shunts as shown opposite[1]:

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 150% 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
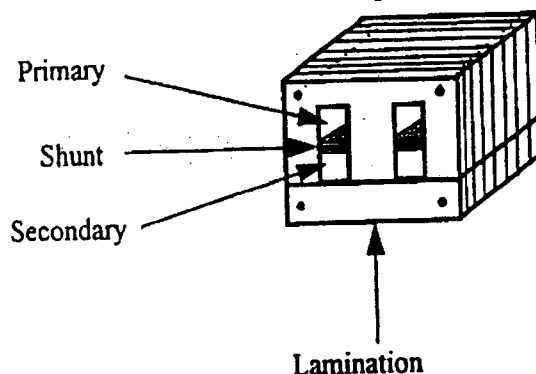
input from the output.

Why Use a Ferro 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.
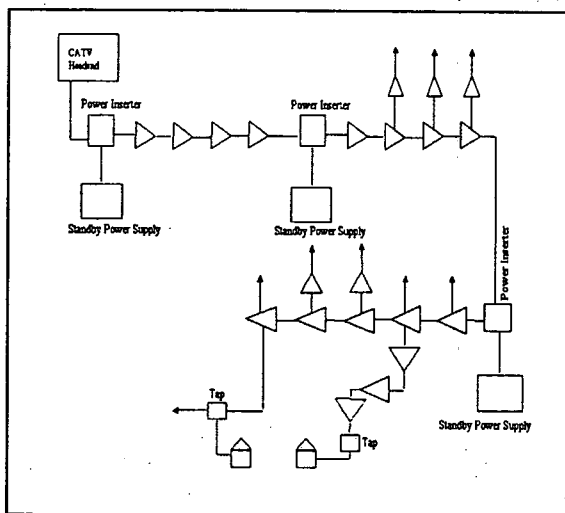
Ohms law dictates that there will be voltage loss when a current passes through a resistance. In this example, the resistance is the coaxial cable between the power supply and the amplifier. Each amplifier has a power pack or module that converts the incoming 60-90 VAC to 24 VDC for use by the amplifier 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 feet x (.76 ohms / 1000 feet) = 1.254 ohms
4.2 amperes x 1.254 ohms = 5.27 VACTRMS (loss)
60 VAC - 5.27 VACTRMS = 54.73 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:
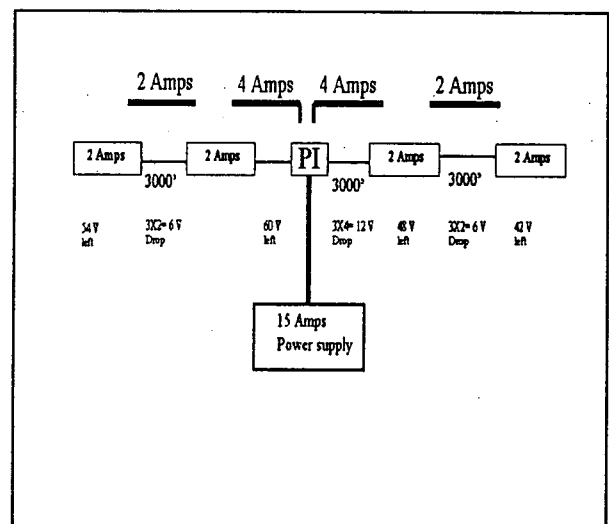
If a standard transformer were to be used in this application, the output voltage of the transformer would follow the input voltage (2:1 transformer converting 120 VAC to 60 VAC). If the end of line were at 42 VAC and the input line dropped to 110 VAC, the resulting voltage at the end of line would be 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 switchmod regulators or "switching power supplies". These units are constant power meaning that they will draw higher amperage at lower voltages (27 VA / 60 VAC = 0.45 amperes or 27 VA / 42 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 +/- 3% of its rated output voltage. This characteristic allows it to function typically from 90 VAC to 140 VAC (or 180 to 280 for the 220 volts nominal input voltage). 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 take 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).

Multiplying the output voltage by the output amperage derives the output power of a ferroresonant transformer. 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 VA x (1/. 90) = 1000 VA. (Input Power)

The input current in amperes can also be calculated:

1000 VA / 120 VACTRMS = 8.3 Amperes or 1000 VA / 240 VACTRMS = 4.167 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 V x 15 A = 1350 VA.

Further, 1350 VA / 120 VACTRMS = 11.25 Amperes or 1350 VA / 240 VACTRMS = 5.625 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

Typical Constructions

In use in the communication industry today are two types of ferroresonant transformers.

These are the non-standby ferroresonant transformer, an example shown next:
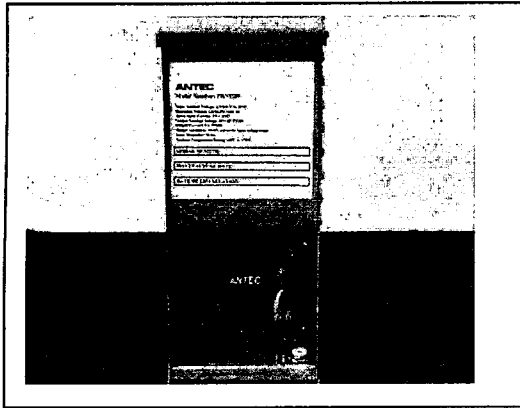
And the standby battery backed power supply. The photo below illustrate the standby unit with the 3 battery backed power supply, which is the most popular arrangement. Longer back up time can be achieved by simply cascading more battery string (s) in parallel.
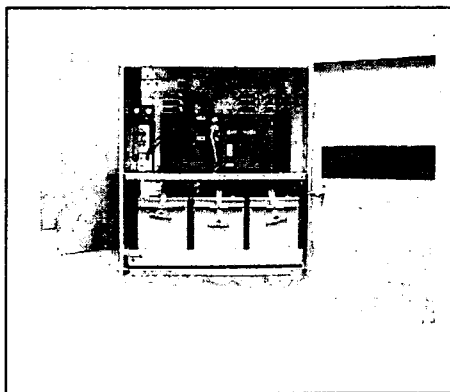
Battery back-up systems or UPS (un-interruptible power source or supply) power supplies can be of either type. . This difference in battery operation time is due to the losses incurred by passing through the ferroresonant transformer (90 % efficiency at full load can be assumed). .

A typical transfer from AC to DC power is depicted next. Note the smooth seamless transfer, from one power source to another.

Transfer from AC to DC source

| 1 | 50 U/a | 50ms/a |
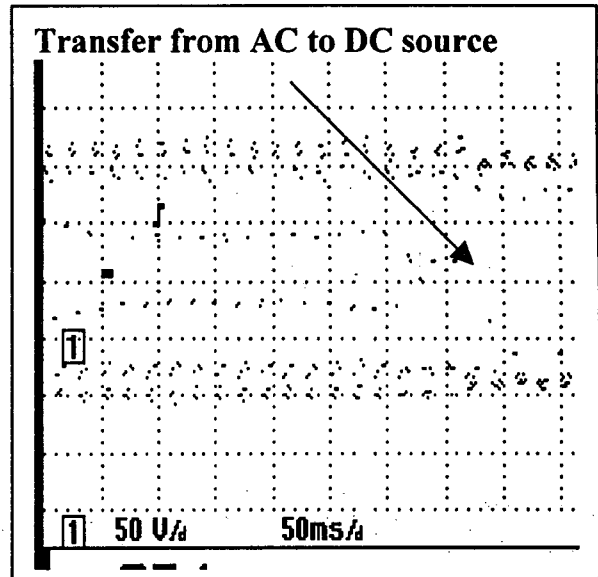
Momentary Input Inrush Currents

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 amps 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.

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 VAC x 15 Amp) x (1/0.90 Efficiency) = 1000 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 minimise the operating cost for the CATV operator. It is therefore recommended that, wherever possible the power supplies be utilized at full load.

Loading being applied to the output load.
[((.75x15)x60)x(1/0.90)=833 Watts]

The under loading 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.

(1)   H. Kaveh et al, Intelec 97

About the Authors:

Dr Hassan Kaveh
B.Sc, M.Sc, PhD, MIEE, C Eng, Eur Ing, MIEEE
is based in Sydney Australia. He can be contacted on Tel: + 61 2 9764 6555
Fax: +61 2 9764 6566
E-mail: hassan.kaveh@arrisi.com

Mr. George Steenton based in Atlanta GA, USA. He can be contacted on Tel: +1 678 473 2000, Fax: +1 678 473 2134, Email: geroge.steenton@arrisi.com