NEW SF_6 TECHNOLOGY BRINGS ENHANCED CAPABILITIES, GREATER RELIABILITY, AND IMPROVED PERSONNEL SAFETY INTO THE FIELD OF DISCONNECT SWITCH LOAD BREAK ATTACHMENTS

David Childress, Marketing Manager-Power Switching Division, Southern States, LLC

Abstract—For more than 50 years vacuum interrupters have been the predominant load break attachment for disconnect switches; however, new SF_6 load break attachments have recently been introduced into the marketplace for transmission class applications (69 kV through 230 kV). These new SF_6 devices have interrupting ratings which exceed that of vacuum interrupters and also provide a significantly greater number of load current interruptions over their operational life. In addition, the ability to visually verify the presence of adequate dielectric prior to operation of the SF_6 device greatly enhances personnel safety. With utilities experiencing continual increases in system loads the need for higher load current interrupting capability devices continues to grow. Also, with more and more taps being added the need for a utility to sectionalize its system in multiple places without requiring complex switching schemes is accomplished simply and cost effectively using this SF_6 technology. Finally, the wheeling of power over long distances produces large amounts of line charging current which can be cleared by these disconnect switch mounted load break attachments. This paper discusses the new SF_6 load break attachment technology for disconnect switches, its relative merits compared to other existing technologies, its common applications, and other special purpose applications.

I. INTRODUCTION

Over the years the devices available to perform the functions of load breaking, loop splitting, and line dropping have taken many forms—among these include circuit breakers, circuit switchers, and disconnect switch mounted interrupter attachments. These disconnect switch mounted interrupter attachments; too, have varied in design based upon their required capabilities. Simple arcing horns (See Figure 1.) and quick break whip type arcing horns (also called buggy whips, quick breaks, and arc restrictors) [See Figure 2.] have been used to drop very short lengths of line or to split very small loops, but for many years the most capable disconnect switch mounted interrupter device for transmission class applications (69 kV through 230 kV) has been the multi-module per phase vacuum attachment (See Figure 3.).

Simple Arcing Horns On A Vertical Break Switch
Figure 1

Quick Break Whip Type Arcing Horns On A Vertical Break Switch
Figure 2

Multi-Module Per Phase Vacuum Interrupter
On A Vertical Break Switch
Figure 3

Recently new SF_6 technology has been introduced into the marketplace (See Figure 4.) which performs all of the same functions that these vacuum interrupters have traditionally accomplished and more. This new SF_6 technology was initially very limited in its available installation options (See Figure 5.), but further design enhancements have led to its widespread use as the most capable, most versatile, and safest of all load break attachments for transmission class rated vertical break disconnect switches.

Newest Single Gap Per Phase SF_6 Interrupter On
A Vertical Break Switch
(2003-Present SF_6 Interrupter)
Figure 4

Single Gap Per Phase SF_6 Interrupter On A
Vertical Break Switch
(1998-2003 Vintage SF_6 Interrupter)
Figure 5

II. AVAILABLE DESIGNS

As previously mentioned the most established disconnect switch mounted interrupter attachment for transmission class applications is the multi-bottle per phase vacuum interrupter (See Figure 3.). These vacuum interrupters are capable of load breaking up to 2000 Amps, line dropping up to 70 Amps, and loop splitting up to 2000 Amps. This multi-functional capability allows disconnect switches equipped with these devices to provide a utility a great deal of versatility in switching schemes.

Recently SF_6 technology has been adapted to the disconnect switch mounted interrupting device role, first taking the form of a porcelain housed SF_6 interrupter (See Figure 5.) and later a composite housed SF_6 interrupter (See Figure 4).

Both of these SF_6 interrupters bettered the vacuum interrupter's capabilities, providing up to 3000 Amps load breaking, up to 300 Amps line dropping, and up to 3000 Amps loop splitting; however, the porcelain housed SF_6 interrupter was limited in available installations due to its physical weight and its operating effort. It was available for mounting on only one manufacturer's specific model of vertical break switch, only with the switch mounted in the horizontal upright position, and only on a support structure adequately robust to handle its imposed operational loads. These limitations hampered its widespread acceptance and prevented its application as an after market retrofit to existing vertical break switches already in the field. In order to provide the functionality desired by utility customers as well as the adaptability to multiple different manufacturers' types of vertical break switches (including those already in service to either convert a no-load isolation switch into a full load break switch or to replace existing vacuum interrupters which had failed or which had had their interrupting ratings exceeded by the current requirements of the installation), multiple different mounting positions (horizontal upright, vertical, and side mount phase-over-phase), and most support structures it was necessary for a further refinement of the design—reducing both physical weight and operating effort.

The latest SF_6 interrupter to enter the marketplace, the composite housed interrupter, accomplished a dramatic weight reduction, and its redesigned mechanism requires a substantially reduced operating effort. Both of these design improvements were accomplished without sacrificing any of its porcelain-housed predecessor's performance ratings.

III. ANALYSIS OF EACH INTERRUPTER TECHNOLOGY

1. Multi-Bottle Per Phase Vacuum Interrupters

The interrupting ratings of multi-bottle per phase vacuum interrupters have been detailed in previous sections, but an additional analysis of other design features of this device is required. Vacuum interrupters for use on disconnect switches are capable of 30 kV peak voltage per bottle, necessitating a series arrangement of bottles per phase for any application which exceeds 30 kV and requires full load break capability (See Figure 6 for an example of this.). For the transmission class load break applications covered by this paper Table 1 illustrates the required number of vacuum bottles in series per phase by system kV rating.

Three Vacuum Bottles In Series Per Phase
On A 69 kV Vertical Break Switch
Figure 6

Table 1. Number Of Vacuum Bottles Required In Series Per Phase To Provide Full Load Breaking Capability By System kV

System kV	Number of vacuum bottles in series per phase to provide full load breaking
69	3
115	5
138	6
161	7
230	8

Once the required number of series connected vacuum bottles per phase is provided it then becomes necessary to equally divide the voltage across each bottle to achieve successful interruption. If any of the voltage dividers fails to adequately divide the voltage then external arcs can be drawn across the vacuum interrupter bottles resulting in a field failure.

Additionally, it is highly desirable from a safety standpoint for any operating personnel to know prior to operating the disconnect switch equipped with these vacuum interrupters that the integrity of the vacuum dielectric still exists, but unfortunately these vacuum interrupters do not have any external visual indication of the presence of adequate dielectric for successful interruption prior to opening them. If the dielectric integrity exists for all bottles in the series stack and if the voltage dividers function properly then a successful interruption is attained; otherwise, external arcing can occur which may be extinguished by the dielectric strength of air once the full air gap is established or which may create a phase to ground or phase to phase fault, necessitating the tripping of protective equipment to clear the line and resulting in significant arcing, pitting, burning, and erosion of the disconnect switch parts with a corresponding reduction in the total operational life of the switch.

2. Porcelain Housed SF_6 Interrupters and Composite Housed SF_6 Interrupters

Since the interrupting ratings of both porcelain housed SF_6 interrupters and composite housed SF_6 interrupters have been detailed in previous sections this section will focus on the analysis of other design features of these devices. Both of these types of SF_6 interrupters are single gap per phase devices, capable of 169 kV peak voltage across the

single gap. The 230 kV SF_6 interrupters are provided with a voltage limiter connected across the single gap which limits the peak voltage to a level within the voltage capabilities of the interrupter, allowing the single gap per phase design to be applied to all transmission class ratings, 69 kV through 230 kV (Figure 7 illustrates a 230 kV installation of these SF_6 interrupter/voltage limiter combinations.). Obviously, the use of a single gap design per phase eliminates the need for any voltage dividers, eliminating several possible points of interrupter failure.

230 kV SF_6 Interrupters With Voltage Limiter
On A Vertical Break Switch
Figure 7

The problem of vacuum interrupters not having visual dielectric indication before opening has also been addressed as each SF_6 interrupter has a pressure gauge on it with color-coded regions to allow visual verification of the presence of adequate dielectric for successful operation prior to opening (See Figure 8.), significantly enhancing personnel safety.

Close Up Of SF_6 Interrupter's Color Coded
Pressure Gauge (Needle In Green Range As
Shown Indicates Adequate Dielectric Is Present
For Successful Interruption.)
Figure 8

An additional design enhancement that the SF_6 interrupters provide versus their vacuum interrupter counterparts is a significantly greater number of total full load break interruptions, namely 2000 full load interruptions versus only 50 full load interruptions for vacuum interrupters (when applied at 2000 Amps [It should also be noted that these SF_6 interrupters are capable of 2000 full load operations when applied at 3000 Amps as well.})

As previously mentioned the major drawbacks limiting the widespread use of the porcelain housed SF_6 interrupter were its weight and its operating effort, both of which restricted its application to a single manufacturer's specific type of vertical break switch installed in a specific mounting position (horizontal upright) and on adequately robust support structures. These design limitations were removed through the dramatic weight and operating effort reductions attained in the composite housed SF_6 interrupters, making them viable for use on any manufacturer's transmission class rated vertical break switch (69 kV through 230 kV) for horizontal upright, vertical, or side mount phase-over-phase installations and on almost any type structure.

IV. COMMON APPLICATIONS

The ability of the multi-bottle per phase vacuum interrupters and the single gap per phase SF_6 interrupters to perform full load breaking, loop splitting, and line dropping applications leads to the need to answer the question: "Where would these devices be used?" The most common answers to this question are

- On the disconnect switches installed on the primary incoming line side of a substation (See Figure 9.); or

Figure 9

- In substation bus tie positions (See Figure 10.); or

Figure 10

- At transmission tap points remote from a substation (See Figure 11.); or

Figure 11

- At transmission tap substations (See Figure 12.); or

Figure 12

- Where one utility connects to another utility; or
- Where a utility connects to an industrial customer; or
- Where a utility connects to an independent power producer (IPP); or
- Any point where an interruptible connection is desired (such as peaking generation provided by a hydro dam, a wind farm, etc.); or
- Any point where single point switching is desired, eliminating complex switching schemes and the detrimental consequences of out of sequence switching.

V. SPECIAL PURPOSE APPLICATIONS

In addition to their ability to perform load breaking, loop splitting, and line dropping functions these SF_6 interrupters have proven themselves quite capable of handling reactor switching applications and occasionally are also found in applications as transformer disconnects, energizing and de-energizing transformers (although these transformer applications are much more commonly served by devices which also have inherent fault protection capabilities such as SF_6 circuit switchers). It is certainly possible that users could find applications for these devices not specifically addressed in this paper.

VI. CONCLUSION

As detailed herein previously and in the table below, by equaling and then bettering all of the capabilities of vacuum interrupters the latest developments in SF_6 interrupter technology for transmission class vertical break switches have firmly established the composite housed SF_6 interrupter as the safest, most capable, most versatile of all load break attachments for transmission class rated vertical break disconnect switches, supplanting the long established vacuum interrupters.

Table 2. Side-By-Side Comparison Of Available Transmission Class Vertical Break Disconnect Switch Mounted Load Break Attachments

	Vacuum Interrupters	Porcelain Housed SF_6 Interrupter	Composite Housed SF_6 Interrupter
Number Of Interrupter Gaps Per Phase	Multiple Based Upon kV Rating	1 At All kV Ratings	1 At All kV Ratings
Visual Dielectric Indication Prior To Operation	No	Yes	Yes
Load Breaking Rating	2000 A	Up To 3000 A	Up To 3000 A
Line Dropping Rating	70 A	Up To 300 A	Up To 300 A
Loop Splitting Rating	2000 A	Up To 3000 A	Up To 3000 A
Number Of Full Load Interruptions	50	2000	2000
Adaptable For Mounting On Any Transmission Class Vertical Break Disconnect Switch	Yes	No	Yes

It is possible that additional advancements in the development of more compact, lighter weight, SF_6 disconnect switch mounted load break attachments could also supplant vacuum interrupters in sub-transmission & distribution voltage ratings as well. Further, it is also possible that additional advancements in the development of SF_6 disconnect switch mounted load break attachments may allow this technology to enter the EHV arena (345 kV and 500 kV applications), offering a very cost effective solution when compared to the presently available SF_6 circuit breakers and SF_6 circuit switchers. For today's transmission class vertical break disconnect switch mounted load break attachments the most current SF_6 interrupters offer users the best combination of capabilities, versatility, long-life reliability, and safety—establishing themselves as the present and the future of transmission class vertical break disconnect switch mounted load break attachments.

VII. BIOGRAPHY

David Childress received his B.S. in Engineering from Mississippi State University in 1991. He joined Siemens Energy & Automation in 1991 as an application engineer responsible for circuit switchers and disconnect switches and later joined Southern States in 1997 holding positions of regional manager, international sales manager, and product manager. He is presently the marketing manager of Southern States Power Switching Division responsible for all Southern States SF_6 products including circuit switchers, load and line switchers, and capacitor switchers.