A Deeper Look into Switchgear and Switchboards

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Everything is relative and depends on perspective. Like the "half empty, half full" parable, the same application could be seen by one as providing a need for switchgear, and by another for a switchboard. This article will delve into that world of uncertainty and attempt to straighten it out just a little.

I. Switchgear Vs Switchboards

Our first target will be the common anxiety of whether to apply switchgear or switchboards. It seems intuitive that switchgear is larger and more expensive but more reliable than switchboards. In order to transition from the intuitive to the real world we established five application case conditions to be compared for analysis. The results are outlined in Table 1. Though this relatively small basis of analysis does not claim to be statistically precise, it was structured towards maintaining a fair comparison. The system configurations are detailed in the table and its notes. To maintain a common field of reference between the two types of equipment we kept the main the same in each (WavePro, drawout) and all the feeders sized at 800A (WP individually-mounted in the switchgear; Molded-case group-mounted in the switchboards). We investigated 480V as well as 208V systems and main bus capacity sizes varying from 2000 to 4000 amperes.

Though actual costs are not shown, net results are represented on a per-unit basis, at a multiple of the lowest item of reference within its grouping. The results are in line with expectations and indicate that, for the cases surveyed, switchgear costs anywhere from 50 to 100% more than its counterpart in group-mounted switchboards. This naturally begs the question of value returned for the added cost of switchgear.

The best source of reference to investigate this matter is IEEE-493-1990 (The Gold Book, Ref 1). Based on extensive failure data evaluations, Table 10, Chapter 3 of that standard, summarizes the statistical failure rate per unit-year of a variety of power system equipment. Though switchgear is not directly compared to switchboards, fixed low-voltage breakers (600V and below, including molded case), as used in group-mounted applications like switchboards, can be compared to low voltage metalclad drawout type breakers, as used in switchgear. The failure rate of switchboards is approximately 156% of switchgear, with an average downtime of four hours per occurrence. Though the basis of the data is historic, the writers believe it is a valid reflection on the production and design philosophies of each product.

Molded case protective devices are intended to meet a market need as economically as possible. Steel framed switchgear was developed for those applications that require reliability and continuity of service. When the above statistics are combined with the anticipated per-event power outage costs for various industries (commercial = $2,299; industrial = $61,710; institutional = $53,455; Ref 2), it is clear why applications concerned with reliability and safety would design around switchgear. Elimination of one failure event within the lifetime of the gear more than provides payback for the increased initial investment.

Yet IEEE-493 also demonstrates that failures occur on a much more frequent basis than that, dependent on environment, maintenance and duration of use. The added features built into the equipment, such as 30 cycle short time withstand rating on the bus, high short time ratings on circuit breakers, drawout construction, and full maintainability, simply become added benefits to the owner. They facilitate up-stream and down-stream coordination, the ability to extend the life and service the breakers without need for a bus outage, as well as increased life expectancy of the gear.

A surprising result in Table 1 is the floor space requirements for each type of equipment. Conventional wisdom would anticipate switchboards to always be significantly smaller than switchgear. These results indicate otherwise. They are effectively comparable for the cases modeled. This is due to the main protective device selected, which plays a significant factor in the footprint of the gear and whether it requires rear access. As a rule-of thumb, any gear depth greater than 45" typically requires rear access and rear working clearances in accordance with NEC 110.26. Had an insulated case main breaker been specified, the 4000A main section dimension could have been reduced to 45" from 50." Even so, it is noteworthy that the group-mounted switchboard lineups remain wider in most cases, and significantly so (62% longer) for some. The lesson to be learned is the importance of properly selecting frame sizes in order to optimize footprint. For example, an 800A rated breaker utilizes the same frame size as a 1200A breaker. Both therefore require the same height spacing and must be single-mounted in a 40" wide enclosure. A 600A breaker, however, can reduce that height spacing by 33% and may be double-width mounted in the same size enclosure. Therefore, in restricted switchboard locations, there is a definite advantage in applying more 600A rather than 800A breakers, or fewer 1200A rather than 800A feeders to downstream sub-distribution panels. More such details can be investigated in the switchboard application publication GET-8032, and DET-196 for switchgear.

II. Switchboard Functionality

Switchboards certainly represent the most widely used low-voltage sub-distribution equipment yet there appears to be significant confusion about many of its capabilities and when to most effectively use them. Table 2 has been prepared as a tool to help shed some clarity on a number of the most commonly raised questions.

Table 2 incorporates the results of twenty-six application case conditions, with variations in switchboard design, which were modeled for analysis. These cases are grouped into five substation sizes ranging from 500 to 2000kVA (three at 480V, two at 208V), each with its resulting short-circuit and continuous current levels defined. Each grouping consists of five case conditions, except the first group, which has six. All cases have been selected to be fairly typical so that the results may be most widely applicable. Each case condition was evaluated as a switchboard design based on slight variations in its make-up specification, then priced and sized. The resulting costs and sizes were per-unitized (PU) on the basis of its substation grouping, as done in Table 1, so the data could be quickly evaluated. It must be understood that these case conditions are only representative for this evaluation. Each application should be evaluated with its unique design requirements taken into account.

Fuses Vs Breakers

A common question raised is whether to apply fuses or breakers. For the cases evaluated, breakers have the clear cost and size advantage. The size advantage is significantly in favor of switchboards using breakers. Fused switchboards are shown to be anywhere from 143% to 213% larger. A sub-category is evaluated for fused switchboards that include the Bolted Pressure Switch (BPS) versus the High Pressure Contact (HPC) switch. Though both are essentially the same price, the HPC switch is about 16% smaller for these cases. Each is classified as a Fused Power Circuit Device and listed under UL977, but only the HPC incorporates an over-center toggle mechanism with high-energy springs and silver-tungsten carbide alloy butt-type contacts. This construction provides it with higher short-time ratings and faster operating speeds (under 3 cycles!), placing it in a breaker-class of reliability. More information can be found in application publication GET-6205.

Bolt-on Vs Plug-in Construction

The flexibility of switchboards has been improved to a level where they are now available in either bolt-on or plug-in construction. In the bolt-on design the protective devices are solidly bolted onto the main electrical distribution bus work. The plug-in construction incorporates a removable module to which the protective device is mounted and permits it to clamp onto the main distribution bus. That connection is made with spring reinforced high tension jaw clamps designed to hug the bus even tighter under high fault conditions (ref. DE-168). The major advantage to plug-in construction is a rapid removal of that protective device from the board without a need to unbolt the breaker (or switch) from the main bus. Though a bus outage is required for safety purposes, this feature minimizes that outage time. Table 2 shows this function only adds about 2% to the cost of the board and has no impact on overall gear footprint size.

Fully- Or Series-Rated Gear

Series-rated gear can provide economy in high short-circuit applications. Such economy was not evident for the short-circuit levels included in the case conditions modeled here. If, however, series-rated equipment had been specified for the project and provided, the equipment and application would be subject to certain restrictions and special labeling and handling requirements as specified in NEC 110.22 and 240.86. The clear lesson to be learned is, if series-rated equipment provides no cost or size advantage, do not request it since added expense in labeling, installation and limitation of application could result. Further insights are available on series ratings in application publication DET-008.

Individually- Vs Group-Mounted Mains

For applications of 1200A or lower, the main protective device can be individually-mounted or group-mounted with the feeders. One special case condition was included in the first substation grouping, Case 3A, to illustrate the possible ramifications of this option. Group mounting the main, in this case, only saves about 4% in cost but results in elimination of one entire enclosure stack thereby decreasing the footprint by 43%! Caution, however, should be exercised here. There are advantages in retaining a separate cable-entry section. These include ease of installation, cooler long term operation of the feeder section (which translates to extended equipment life), and complete isolation of power from the feeder section when the main is opened. These are significant benefits for a mere 4% cost adder, but only if floor space permits.

Summary

The case conditions and comparisons evaluated here demonstrate how seemingly minor variations in design and specification can have significant impact on a project's economics and space efficiency. They have further served to illustrate how general perceptions may be out of line with the reality of any given application since each is unique and merits its own evaluation.

Comments

All evaluations presented in this article are based on the use of GE type AKD Switchgear and GE type Spectra Switchboards, configured as detailed within the referenced tables and within the notes provided for those tables. Results may vary with other types of equipment and/or varying configurations and options.

References

1. IEEE Std 493-1990, "Design Of Reliable Industrial And Commercial Power Systems", Chapter 3, pp 54, Table 10.

2. Chowdhury, A. A., Koval, D. O., "Balancing Society's Cost Of Electric Grid Blackouts And The Worth Of Improved Electric Grid Reliability", Keynote Presentation and Paper at the 16th International Conference on Systems Research, Informatics and Cybernetics, pp 4, Upcoming July 29, 2004, Baden-Baden, Germany.

Table 1

Switchgear Vs Switchboard - Comparison Of Sizes And Cost

Case #	Voltage	Sub KVA	Gear Type	Main CB Amp Rating	Feeder Types	Per Unit Net Cost	Line-up Dim'ns (in.) W	Line-up Dim'ns (in.) D	Per Unit Footprint
1	480	1500	Switchgear	2500	WP	1.7	74	60	1.1
2	480	1500	Switchboard	2500	MCCB	1.0	80	50	1.0
3	480	2000	Switchgear	3200	WP	1.5	74	60	0.7
4	480	2000	Switchboard	3200	MCCB	1.0	120	50	1.0
5	480	2500	Switchgear	4000	WP	2.0	96	60	1.0
6	480	2500	Switchboard	4000	MCCB	1.0	120	50	1.0
7	208	500	Switchgear	2000	WP	1.6	66	60	1.0
8	208	500	Switchboard	2000	MCCB	1.0	80	50	1.0
9	208	750	Switchgear	3200	WP	1.8	74	60	0.7
10	208	750	Switchboard	3200	MCCB	1.0	120	50	1.0

Notes:

1. In all cases mains are elect operated Wave-Pro CB's, drawout, LSI (with GF at 480V only); feeders are manually operated, rated 800A, LSI (with GF at 480V only).
2. The switchgear includes all drawout units; Switchboard construction includes group mounted feeders. All boards are rated 65kAIC.
3. Capacity of feeder circuits equals approximately 200% of substation capacity, ie: 4000A gear includes qty 10 800A feeders.
4. Each line-up incorporates main bus CPT, CT's, PT's, power quality main meter, 200kA TVSS.
5. Footprint comparison assumes main depth x lineup width. Though group-mounted stacks are shallower than mains, that space remains unsalvageable.
6. Cost comparison is based on budgetary net project values.
7. WP = Wave-Pro steel frame breakers; MCCB = Molded-Case Circuit Breaker.

Table 2?
Switchboard Analysis - Comparison of Sizes

Case #	Voltage	Sub kVA	Sh Ckt kA	Main Breaker Type	Main Breaker Amp Rating	Feeder Type	Feeder Plug-In/Bolt-On	Per Unit Net Cost	Line-up Dim'ns (in.) W	Line-up Dim'ns (in.) D	Per Unit Footprint
1	480	1000	25	BPS	1200	FU	B-O	1.60	120	30	2.06
2	480	1000	25	HPC	1200	FU	B-O	1.57	120	25	1.71
3	480	1000	25	CB	1200	CB	B-O	1.00	70	25	1.00
3A	480	1000	25	CB	1200	CB	B-O	0.96	40	25	0.57
4	480	1000	25	CB	1200	CB	P-I	1.01	70	25	1.00
5	480	1000	25	CB	1200	CB-Series Rtd	B-O	1.00	70	25	1.00
6	480	1500	42	BPS	2000	FU	B-O	1.38	120	30	1.71
7	480	1500	42	HPC	2000	FU	B-O	1.36	120	25	1.43
8	480	1500	42	CB	2000	CB	B-O	1.00	70	30	1.00
9	480	1500	42	CB	2000	CB	P-I	1.02	70	30	1.00
10	480	1500	42	CB	2000	CB-Series Rtd	B-O	0.90	70	30	1.00
11	480	2000	50	BPS	2500	FU	B-O	1.34	170	35	2.13
12	480	2000	50	HPC	2500	FU	B-O	1.32	170	30	1.82
13	480	2000	50	CB	2500	CB	B-O	1.00	80	35	1.00
14	480	2000	50	CB	2500	CB	P-I	1.02	80	35	1.00
15	480	2000	50	CB	2500	CB-Series Rtd	B-O	1.00	80	35	1.00
16	208	500	35	BPS	1600	FU	B-O	1.55	120	30	1.71
17	208	500	35	HPC	1600	FU	B-O	1.53	120	25	1.43
18	208	500	35	CB	1600	CB	B-O	1.00	70	30	1.00
19	208	500	35	CB	1600	CB	P-I	1.01	70	30	1.00
20	208	500	35	CB	1600	CB-Series Rtd	B-O	1.00	70	30	1.00
21	208	750	42	BPS	2500	FU	B-O	1.42	170	35	2.13
22	208	750	42	HPC	2500	FU	B-O	1.40	170	30	1.82
23	208	750	42	CB	2500	CB	B-O	1.00	80	35	1.00
24	208	750	42	CB	2500	CB	P-I	1.08	80	35	1.00
25	208	750	42	CB	2500	CB-Series Rtd	B-O	1.00	80	35	1.00

Notes:
1. All BPS (Bolted Pressure Switches) and HPC (High Pressure Contact Switches) include Blown Fuse and Phase Failure protection.
2. All mains are 100% rated, stationary, manually operated, include GF at 480V only. Main CB trip units also include LSI functions.
3. All mains are individually mounted, all feeders are group mounted; except case # 3a which is totally group mounted.
4. Each lineup includes a power quality meter, 200kA/mode TVSS, heat rated CU bus, CPT, service entrance label.
5. Each linup is fully rated except where feeders are noted 'CB-Series Rtd.'
6. Amount of feeders based on 150% of bus rating with mix as follows:1200 bus = 6-100A, 2-200A, 2-400A; 1600A bus = 4, 2, 4; 2000A bus = 2500 bus = 6, 4, 6.
7. Price evaluation based on budgetary user net market values as of June 2004.
8. Footprint evaluation based on switchboard length, and depth of deepest section.