Systecon®
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P/S vs. VariPrime kW COMPARISON *Case Study*

For many years, central plants have been designed using primary/secondary (P/S) pumping arrangements. Under this design practice, a constant speed pump is used to provide constant flow across the evaporator barrel of each chiller. The flow of this pump is based on the chiller tonnage and the system differential temperature (ΔT). The head pressure is designed to pump the water through the chiller and in a small loop in the central plant only. The distribution of this water is achieved by utilizing a variable speed secondary pumping system that is designed for the full system flow. The head pressure of the secondary pump(s) is designed to pump the water through all terminal units in the system and back to the central plant. In a typical design, the primary pumps are typically low head pumps, and the secondary pumps are typically high head pumps. Variable speed drives are utilized on the secondary pumps to lower the pump horsepower when the system does not require full load.

The standard P/S design has been used for many years with great success. With the simple control logic required to sequence the primary pump on with each chiller, chiller plant management was straightforward. As the flow in the system increased to point where it exceeded the primary pump flow of the operating chiller pumps, the next chiller in the sequence was brought on. The system flow was continuously monitored to sequence chillers on and off as required. Others methods were also used to determine when to sequence chillers on and off, such as flow or temperature switches in the decoupler pipe, supply temperature monitoring, chiller kW output, etc. The key was always keep more flow in the primary loop by adding chillers and primary pumps than was required in the secondary loop to maintain a constant system supply temperature.

While this design has been successfully used for many years, newer technology has lead to an evaluation of this design based on installed costs and operating costs. Although P/S is an efficient operating system and allows the secondary pumps to perform at part loads, this design method requires two sets of pumps to make the system work. Along with each pump that must be installed, the associated valves and fittings required add additional pressure losses to the system, as well as additional losses through pump and motor inefficiencies. Overall, there are potentially better ways to design this system.

For over five years now, Systecon has been proposing variable volume systems utilizing a single set of pumps, the VariPrime™ system. The VariPrime system employs one set of variable volume pumps pumping through the chiller(s) and out to the system. A modulating valve and controls are integrated into the design to maintain minimum and/or rated flows of each chiller. With the Systecon system, the pumps are headered to allow maximum flexibility with the system design and operation, and still maintain minimum kW usage from the pumping system. This system with a 1000 Ton chiller can be analyzed as follows:

The kW for each pump is defined as:

$$\frac{\text{Flow} \times \text{Head} \times .746}{3960 \times \text{Efficiency}}$$

The primary pump kW is:

$$\frac{2400 \times 40' \times .746}{3960 \times (.90 \times .74)} = 27.2 \text{ kW}$$

The secondary pump kW is:

$$\frac{2400 \times 100' \times .746}{3960 \times (.90 \times .74)} = 67.8 \text{ kW}$$

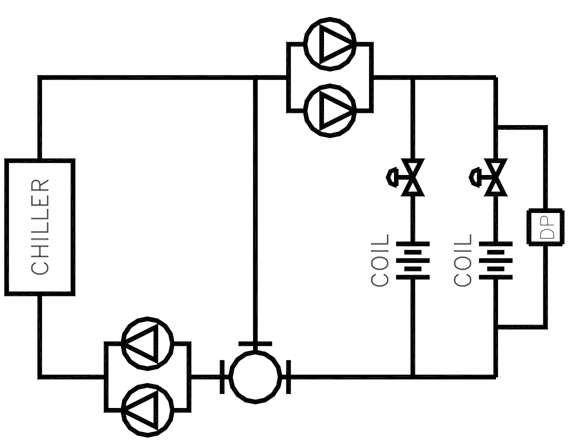
The associated VariPrime pump would be designed for 2400 GPM but only at 130' TDH. The total design head for the P/S system was 140' (40' + 100'). The VariPrime system benefits from less pressure drop than that incurred in the second set of pumps needed for the P/S system.

The VariPrime pump kW is:

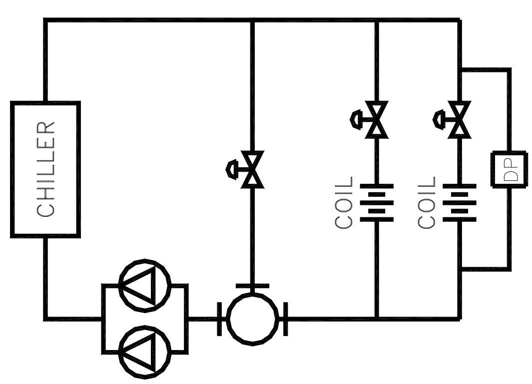
$$\frac{2400 \times 130' \times .746}{3960 \times (.90 \times .74)} = 87.5 \text{ kW}$$

The kW difference between the P/S system and the VariPrime system is 7.4 kW, or about 7.8% at full load. Also, if any backup pumps are required, the P/S system is going to require four pumps compared to two for VariPrime.

PRIMARY/SECONDARY



VARIABLE PRIMARY
(VARIPRIME)



For any given system this analysis can be made. Most simple systems utilizing similar size and type of chillers are going to bear the same results, where the VariPrime system will **ALWAYS** use less energy at full load, and require less pumps. This helps with floor plan space and installed cost along with the energy savings. The amount of savings will depend on the number of chillers and the amount of pump head required for the various pumps on each system.

Since most systems do not run at full load all of the time, nor are they designed with one large chiller, the VariPrime system needs to be analyzed in a multiple chiller system. Our example system will be a 3000 ton plant with three 1000 ton chillers. The P/S design will have three 2400 GPM pumps designed at 40' TDH, and three secondary pumps designed 2400 GPM @ 100' TDH. The VariPrime system will have three pumps 2400 GPM @ 130' TDH.

For the comparison, several assumptions need to be made. The best way to start is to assume that the chiller must be maintained at full flow, whether the system is P/S or VP. This will allow any chiller type to be used, and the pumping system will not change. The controls for the VariPrime system will modulate to maintain constant flow through the evaporator, and variable flow and variable head out to the system, with the use of the modulating valve. A modeling program has been used to determine the system head loss through the system piping at reduced flow. The program then determines the proper pump(s) speed and associated kW to serve the load. For the P/S system, the evaporator pump kW is added to the secondary pump kW. If two chillers are running, both evaporator pumps are being used. The VariPrime pumping kW is calculated by figuring the proper pump speed to maintain constant flow through each evaporator running, plus the head required to pump the system load from one set of pumps (the full report is attached in an appendix.) The resulting table was generated:

		Primary Pumps		**Secondary Pumps**		**Variprime System**	
System GPM	Hours	C.S. KW	C.S. KWH	V.S. KW*	V.S. KWH	V.S. KW*	V.S. KWH
720	297.84	27.15	8087.67	6.60	1965.74	32.10	9560.66
1440	586.92	27.15	15937.48	13.10	7688.65	34.20	20072.66
2160	1051.20	27.15	28544.73	21.10	22180.32	36.60	38473.92
2880	1585.56	54.31	86109.95	31.30	49628.03	79.60	126210.58
3600	1690.68	54.31	91818.89	44.10	74558.99	87.20	147427.30
4320	1568.04	54.31	85158.46	59.80	93768.79	96.50	151315.86
5040	989.88	81.46	80638.87	80.00	79190.40	101.60	100571.81
5760	613.20	81.46	49953.28	105.00	64386.00	191.80	117611.76
6480	306.60	81.46	24976.64	137.50	42157.50	211.30	64784.58
7200	70.08	81.46	5708.95	174.20	12207.94	231.10	16195.49

8760	476,935	447,732	792,225
Total Hrs./Yr.	Total C.S. KWH	Total V.S. KWH	Total V.S. KWH

Percentage kW Savings: 14.32%

The resulting table shows a 14% savings for the VariPrime system over and above the P/S system. The results will vary slightly depending on the difference in head in the distribution loop. This may not seem like a significant savings for the complexity of the controls to make the VariPrime system work, which is a common concern. However, what if we took advantage of the chillers ability to accept varying flows? Most centrifugal chillers designed at 10°ΔT will allow flow down to 50% of rated flow. For our example, we run the chiller at any flow rate above 1200 GPM. This allows our VariPrime system the chance to lower its flow (and kW draw), and take full advantage of the variable speed pumps. The P/S system cannot part load the constant flow primary pump. The new table is:

		Primary Pumps		**Secondary Pumps**		**Variprime System**	
System GPM	Hours	C.S. KW	C.S. KWH	V.S. KW*	V.S. KWH	V.S. KW*	V.S. KWH
720	297.84	27.15	8087.67	6.60	1965.74	12.50	3723.00
1440	586.92	27.15	15937.48	13.10	7688.65	14.80	8686.42
2160	1051.20	27.15	28544.73	21.10	22180.32	24.10	25333.92
2880	1585.56	54.31	86109.95	31.30	49628.03	37.10	58824.28
3600	1690.68	54.31	91818.89	44.10	74558.99	53.40	90282.31
4320	1568.04	54.31	85158.46	59.80	93768.79	74.20	116348.57
5040	989.88	81.46	80638.87	80.00	79190.40	101.60	100571.81
5760	613.20	81.46	49953.28	105.00	64386.00	136.60	83763.12
6480	306.60	81.46	24976.64	137.50	42157.50	180.30	55279.98
7200	70.08	81.46	5708.95	174.20	12207.94	231.10	16195.49

8760	476,935	447,732	559,009
Total Hrs./Yr.	Total C.S. KWH	Total V.S. KWH	Total V.S. KWI

Percentage kW Savings: 39.54%

The pumping savings on this VariPrime system has decreased a full 40% from the base P/S system. It is important to note that ASHRAE data was used for a typical large office building in the Midwest. Total run hours and location of the facility will effect the final numbers. However, since this building is a good average building, these types of savings are seen on a consistent basis for any pumping system.

The preceding analysis is accurate for a building that works perfectly. The plant can easily be sequenced based on system flow, since the terminal units are designed to always return a constant temperature drop across the load. However, many buildings or systems cannot return the constant temperature drop required to make the P/S system work. Many systems have a combination of terminal devices that do not return a constant temperature drop, such as room units in a school or hotel. Depending on the fan speed, these units require full flow but have a varying temperature drop. This will cause problems with the chiller loading and sequencing algorithms.

As an example, let's assume that the load can only return 8°F ΔT. With the plant designed in the standard P/S method, the constant flow evaporator pump is designed for 2.4 GPM/ton at 10°F ΔT, or 2400 GPM. At 8°F ΔT, the chiller can only be loaded to 800 tons. This means that the standby chiller will have to be turned on sooner, with the accompanying evaporator pump turned on as well. With the VariPrime system, the variable speed evaporator speeds can continue to pump water through the chiller until it is fully loaded. At 8°F ΔT, this would be 3000 GPM. Our data table now shows the following energy savings:

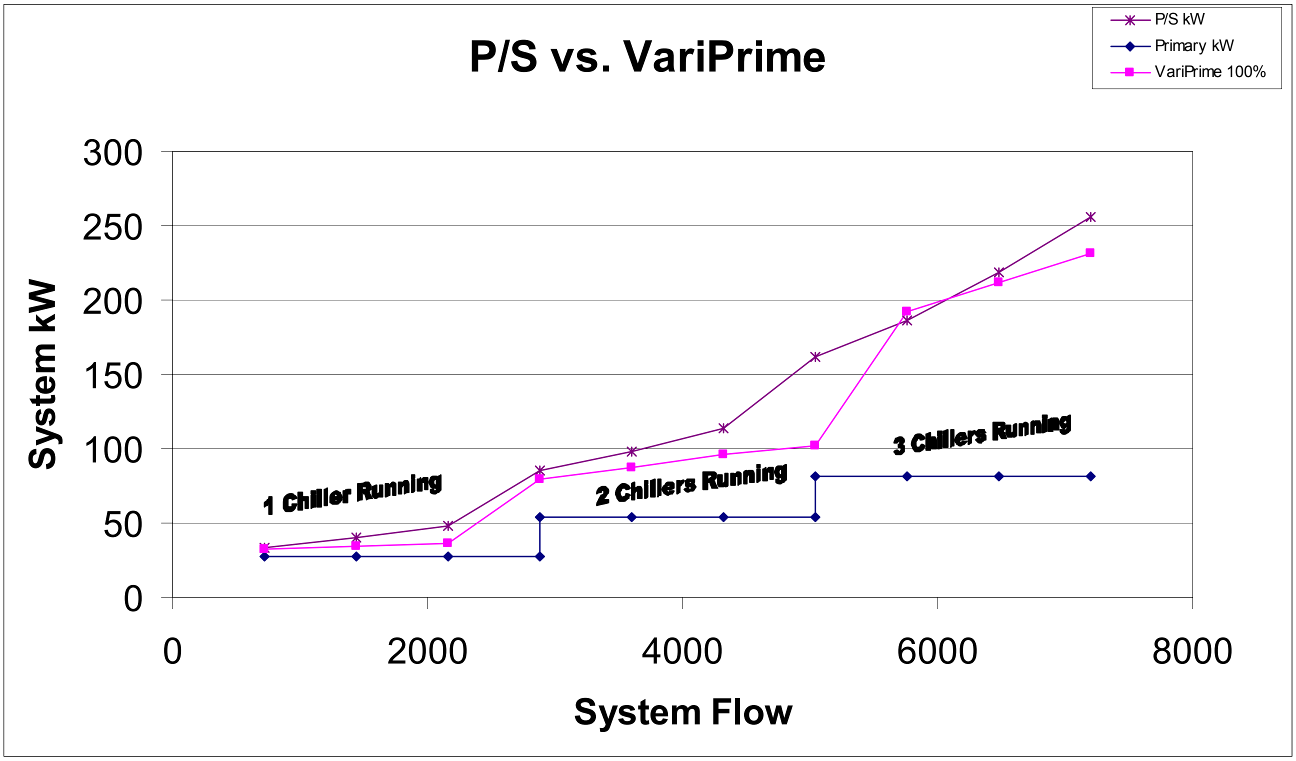
		Primary Pumps		**Secondary Pumps**		**Variprime System**	
System GPM	Hours	C.S. KW	C.S. KWH	V.S. KW*	V.S. KWH	V.S. KW*	V.S. KWH
720	297.84	27.15	8087.7	6.60	1965.7	12.50	3723.0
1440	586.92	27.15	15937.5	13.10	7688.7	14.80	8686.4
2160	1051.20	54.31	57089.5	21.10	22180.3	24.10	25333.9
2880	1585.56	54.31	86109.9	31.30	49628.0	37.10	58824.3
3600	1690.68	54.31	91818.9	44.10	74559.0	53.40	90282.3
4320	1568.04	81.46	127737.7	59.80	93768.8	74.20	116348.6
5040	989.88	81.46	80638.9	80.00	79190.4	101.60	100571.8
5760	613.20	81.46	49953.3	105.00	64386.0	136.60	83763.1
6480	306.60	81.46	24976.6	137.50	42157.5	180.30	55280.0
7200	70.08	81.46	5708.9	174.20	12207.9	231.10	16195.5

8760	548,059	447,732	559,009
Total Hrs./Yr.	Total C.S. KWH	Total V.S. KWH	Total V.S. KWI

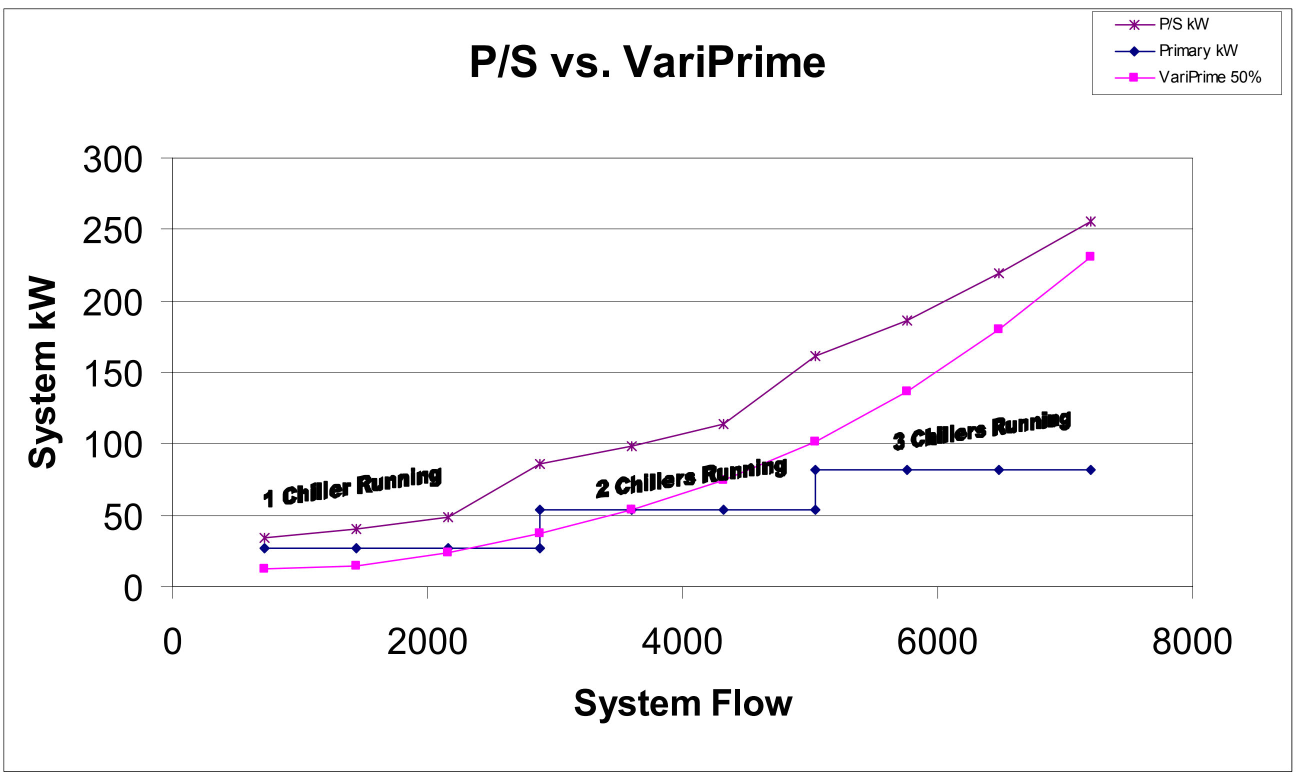
Percentage kW Savings: 43.86%

With the variable speed pumps and piping arrangement of the VariPrime system, the pumping system for the plant can now operate up to 44% more efficient that the P/S design. The last analysis would yield even greater savings if the condenser water pump and cooling tower fan were added into the savings. Also, for most centrifugal chillers, the most efficient point is above 80%, so the P/S plant does not allow the chillers to be fully optimized. All of these factors point to a design that must be able to change the flow across the chillers in response to varying differential return temperatures. The VariPrime system allows this.

The conclusions are simple. A VariPrime system, properly designed and operated, will save operating costs on the pumping energy of any system. There will also be an installed cost savings, which can also reach significant portions. This straightforward analysis does not even take into account the many operational savings and potential chiller operating cost savings that have been proven in over 200 facilities across the country utilizing the Systecon VariPrime system.



Graph 1: Chiller plant kW comparing P/S system versus chillers with 100% rated flow requirements.



Graph 2: Chiller plant kW comparing P/S system versus chillers with 50% rated flow requirements.