Next Generation DCP Optimization using MV VSDs

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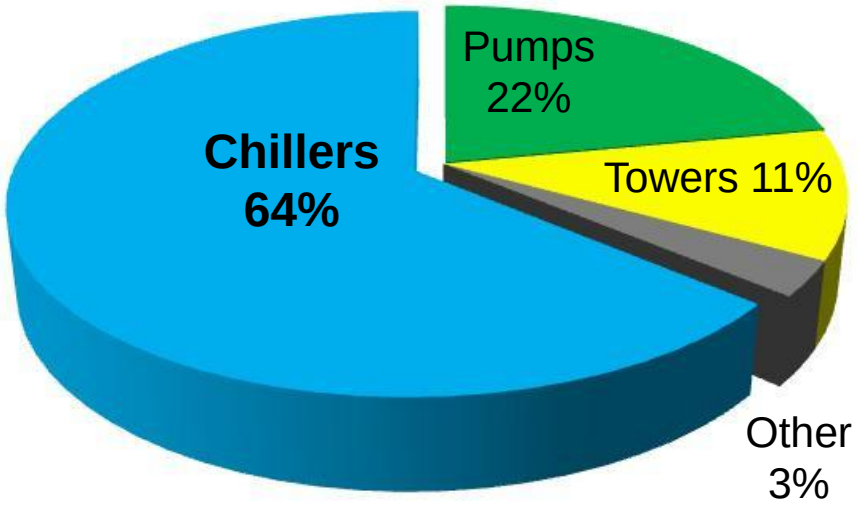
Central Plant Optimization

Energy and operating Costs

- Electricity costs are rising at rates greater than inflation
- Owners are seeking a “total cost of ownership” solution

Total Chiller Plant Energy Use



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Background – Why are talking VSD Chillers

In a District Cooling Plant, Chillers, by far, have the Largest Energy Demand.

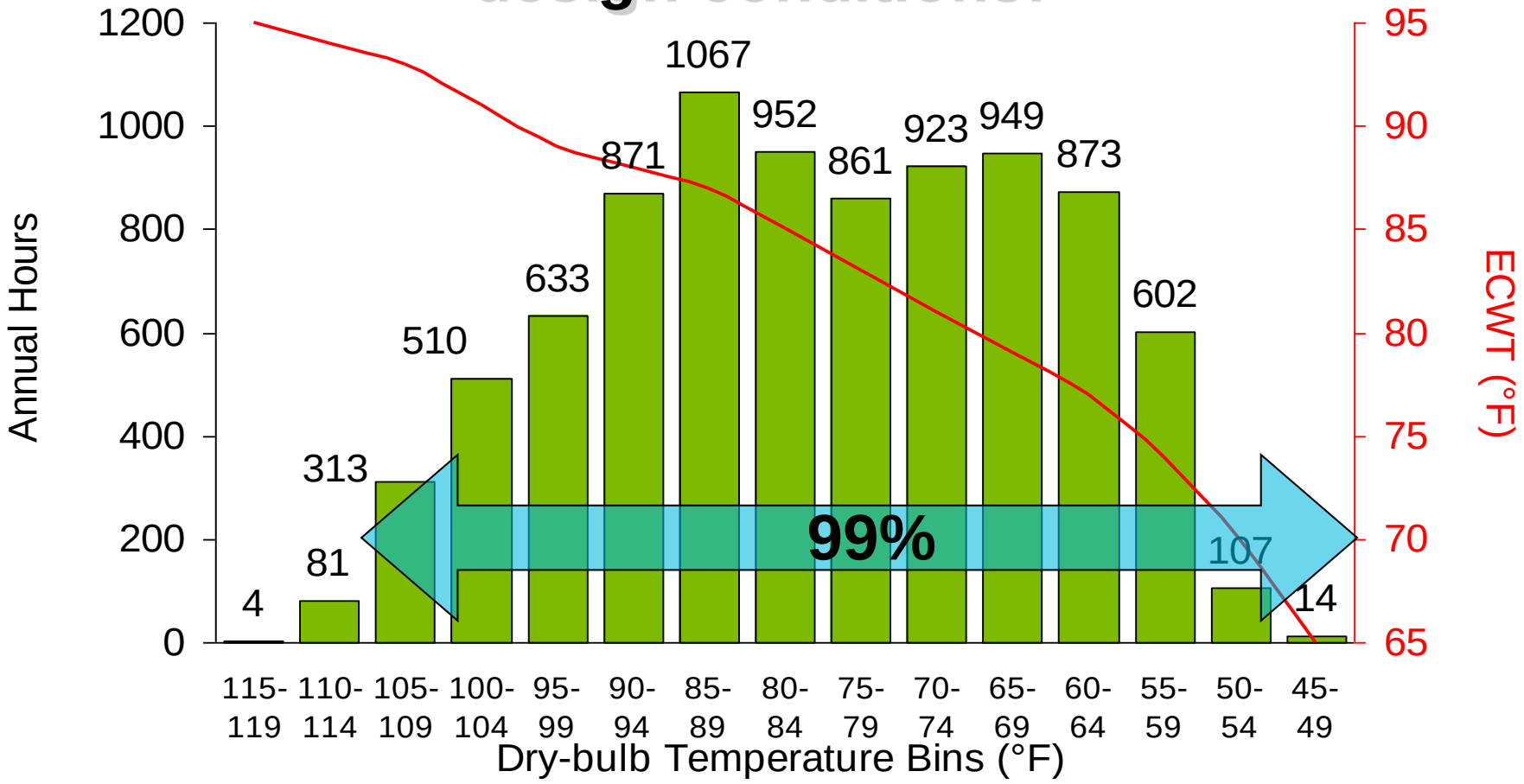
Chillers Spend more than 99% of Operating hours at Off-design Conditions.

- Simultaneous occurrence of 100% Load and Design Outdoor Conditions is very unlikely.

Compressor Running at Lower Speeds, whenever possible, Consumes Less Power and Can Potentially save upto 30% of Annual Energy Consumption.

General Weather Pattern in the Gulf

Less than 1% of chiller run hours are at design conditions!



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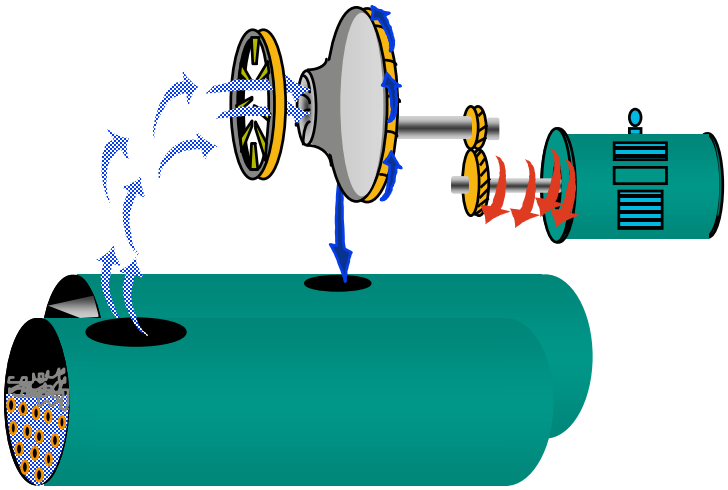
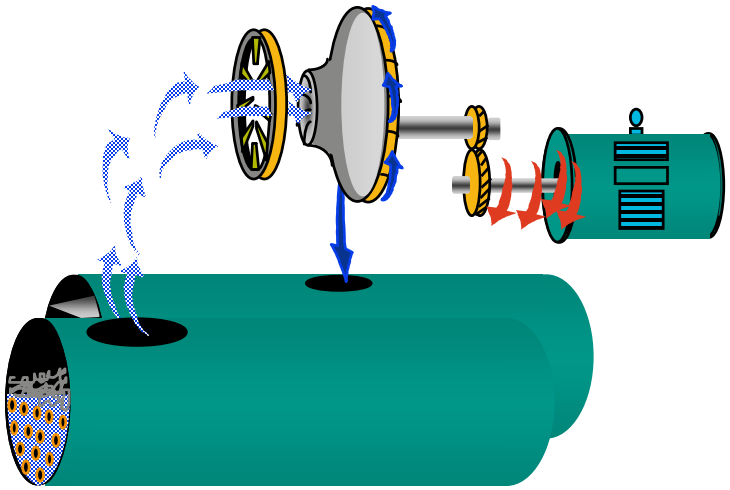
Centrifugal Chillers at Design Conditions

Constant Speed



Loaded Chiller : PRVs Open
Motor at Design Speed

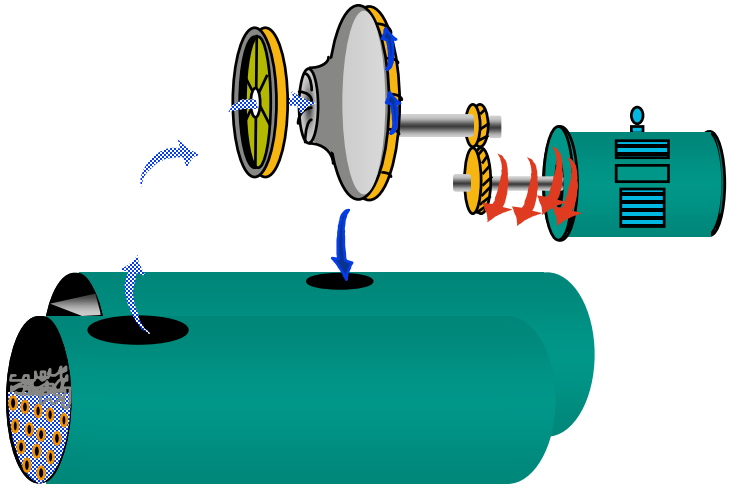
Variable Speed



Loaded Chiller : PRVs Open
Motor at Design Speed

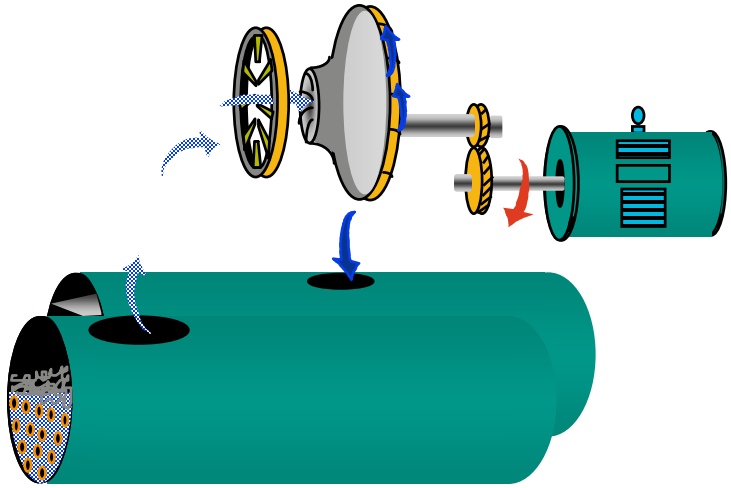
Centrifugal Chillers at Off-Design Conditions

Constant Speed



PRV close as load decreases
Motor speed remains constant at full

Variable Speed



Optimizes compressor efficiency
Motor speed slows down
Optimizes PRV position
Consumes less energy

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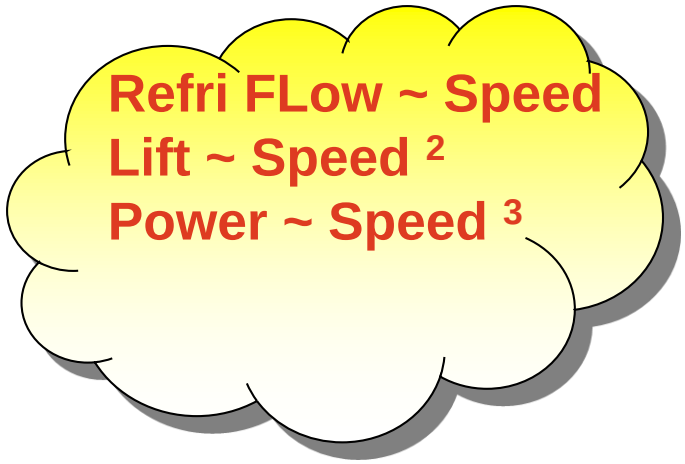
Centrifugal Chillers at Off-Design Conditions

With the use of VSD, Can we do away with the Inlet Vanes ?

No, Certainly not.



A balance between the speed reduction and vane throttling is needed for ‘Surge-Free’ Operation at Low Load conditions.

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Centrifugal Chillers at Off-Design Conditions

Chilled Water Temp.

Temp. Setpoint

Evap / Cond Pressure

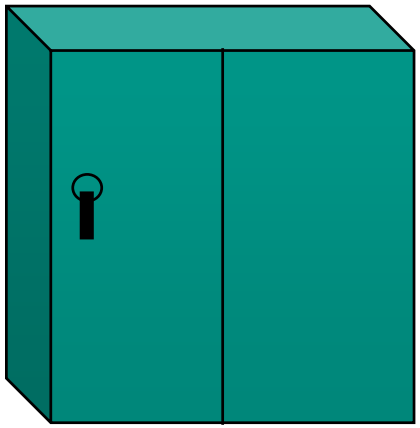
PRV Position

Actual Motor Speed

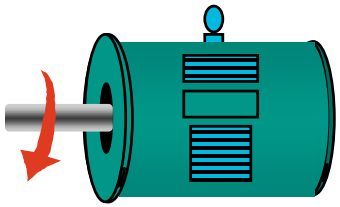
Refri FLow ~ Speed

Lift ~ Speed ^{2}

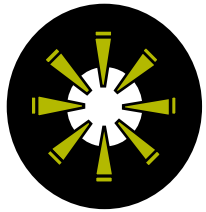
Power ~ Speed ^{3}



Optimum Motor Speed



Optimum PRV Position



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Additional Benefits of a VSD

- Improved and Constant PF of 0.98
  - Eliminates PF correction Capacitors
  - Reduces Current for Same Power
- Eliminates Inrush Current (<100% FLA)
  - Enhances motor life
  - Reduces Emergency Power Generator Size.
- Reduced driveline wear
- Reduced Sound Level at Lower Loads.
  - At night time, when you need low noise operation.
- Eliminates ill-effects of exaggerated design parameters.
  - Higher Condenser Water Temp
  - Fouling Factors

VSD Chiller : District Cooling Application

Can I apply this Breakthrough Technology to District Cooling?

But….I have so many chillers, which are sequenced and hence run close to full load most of the time

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VSD Chiller : District Cooling Application

We are very familiar with VSD application where the speed is Modulated to maintain static pressure at varying flow-rate.

- Air Handling Units in Variable Air Volume systems
- Secondary Chilled Water Pumping

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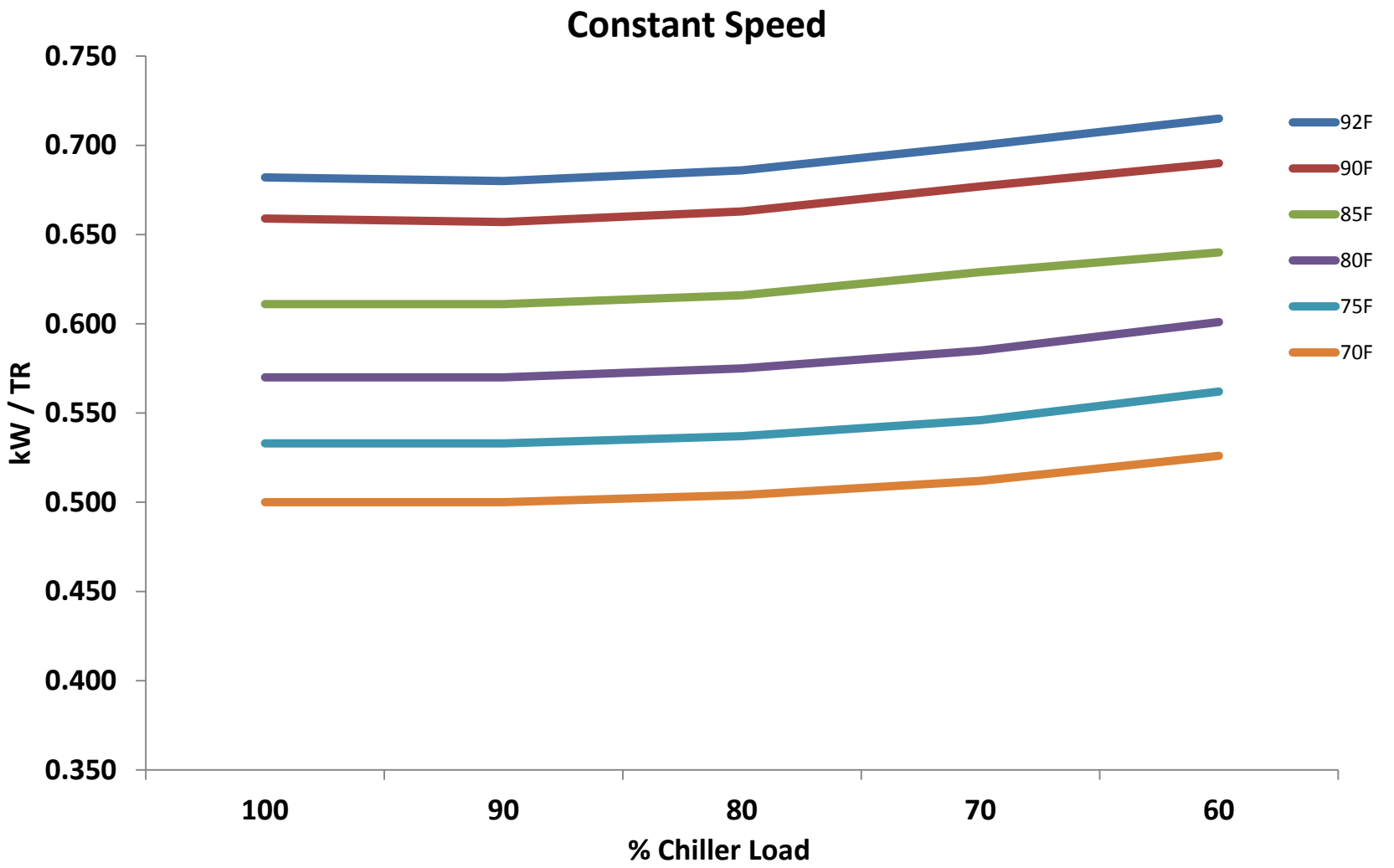
VSD Chiller : District Cooling Application

Centrifugal Chiller Compressor are also subject to situations, where the static pressure is reduced while the flow rate needs to be maintained

Imagine….Reduced Cond pressure due to lower Wet Bulb conditions and constant refrigerant flow rate due to constant cooling load.

Impacts of Cooling Water Temp & Load on COP



Chiller Best Efficiency is at near full load conditions.

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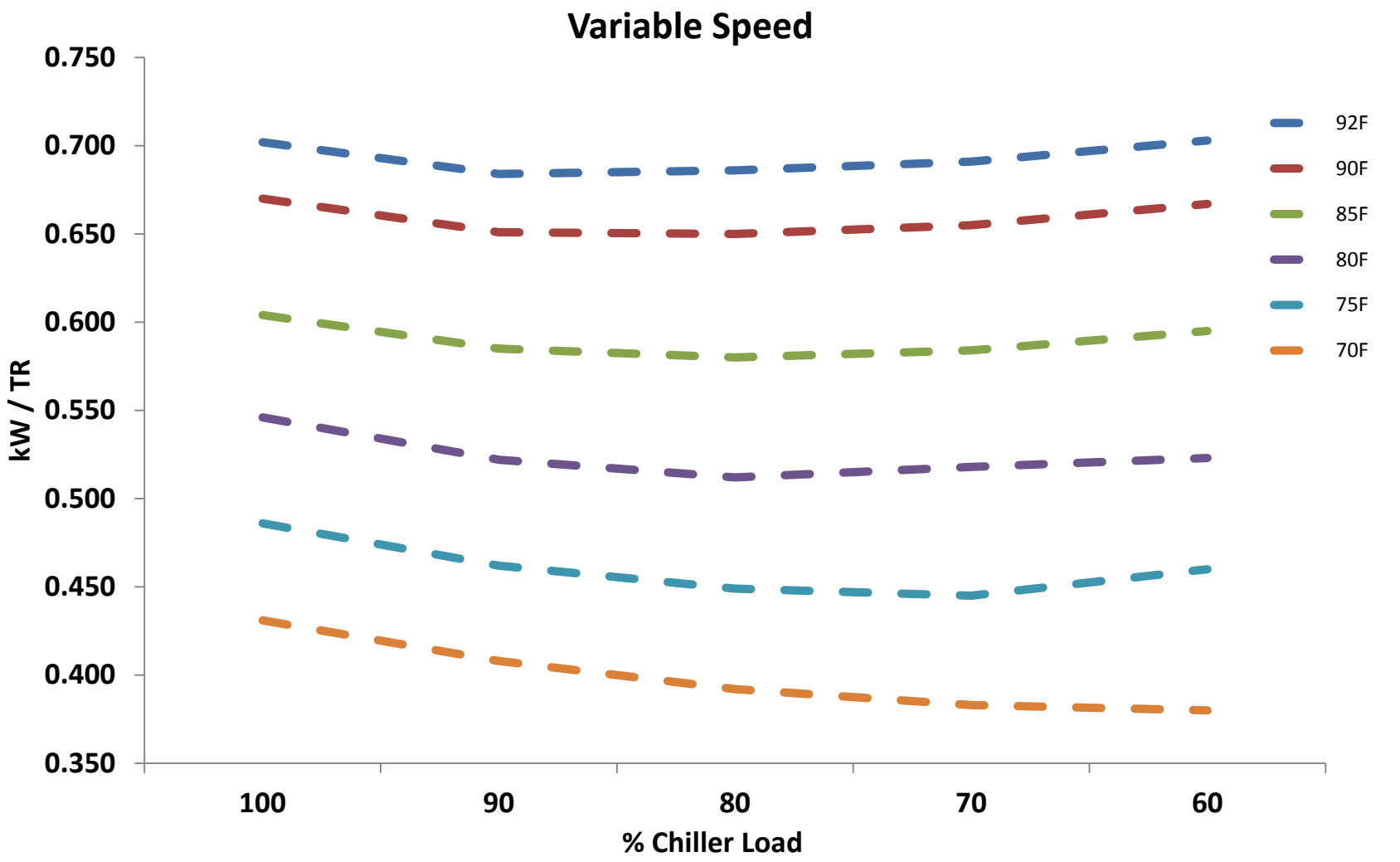
Impacts of Cooling Water Temp & Load on COP



Constant Speed Chiller Best Efficiency is at near-full load condition.

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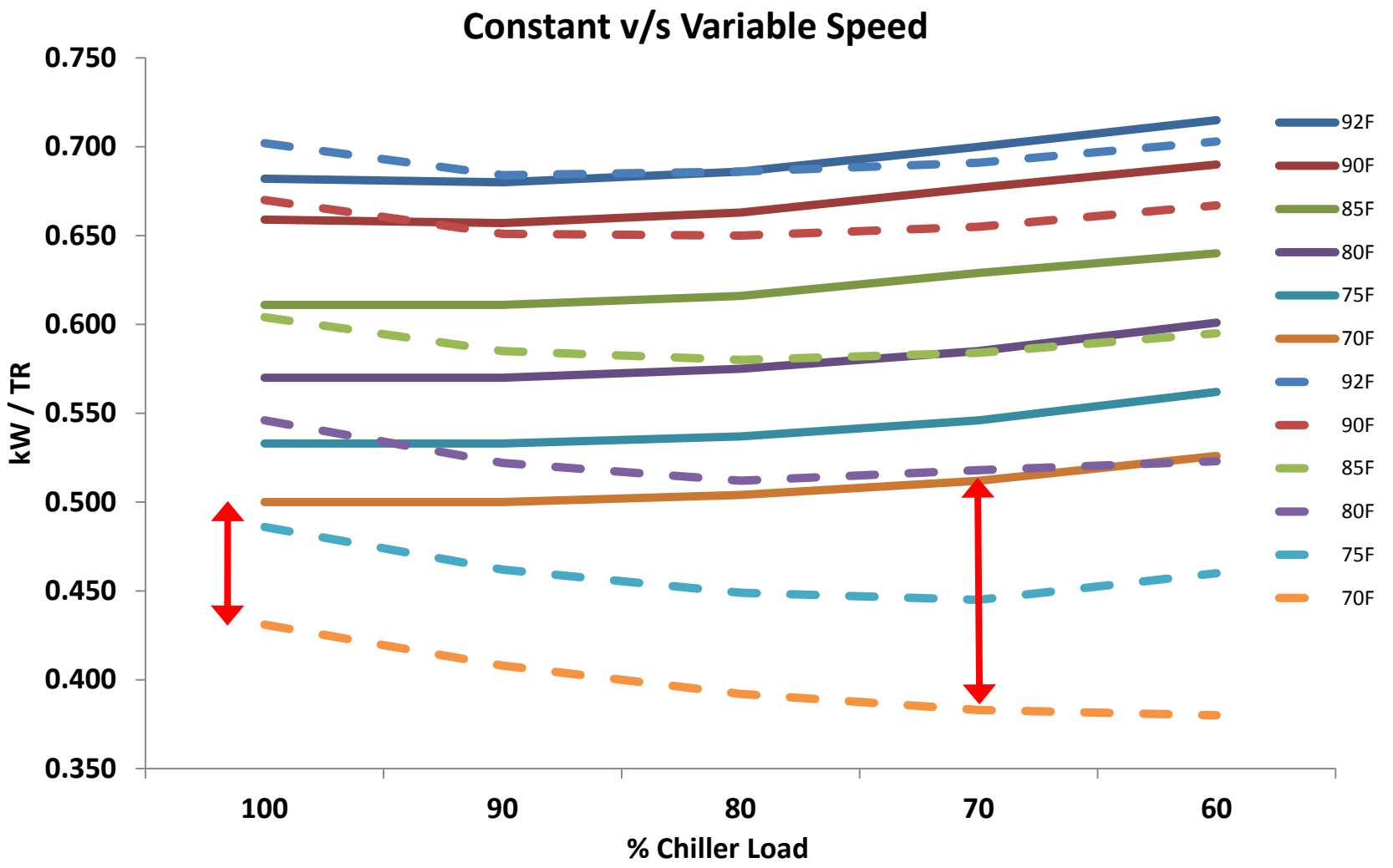
Impacts of Cooling Water Temp & Load on COP



VSD saves power even at Full load and more so at lower loads

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Impacts of Cooling Water Temp & Load on COP

Off Design Performance of a Typical Centrifugal Chiller								
% Chiller Load		Input kW/Ton at Varying ECWT						
		92.3F	90F	85F	80F	75F	70F	65F
100	Constant Speed	0.682	0.659	0.611	0.57	0.533	0.5	0.469
	Varibale Speed	0.702	0.67	0.604	0.546	0.486	0.431	0.383
	% Difference	2.9%	1.7%	-1.1%	-4.2%	-8.8%	-13.8%	-18.3%
90	Constant Speed	0.68	0.657	0.611	0.57	0.533	0.5	0.469
	Varibale Speed	0.684	0.651	0.585	0.522	0.462	0.408	0.358
	% Difference	0.6%	-0.9%	-4.3%	-8.4%	-13.3%	-18.4%	-23.7%
80	Constant Speed	0.686	0.663	0.616	0.575	0.537	0.504	0.469
	Varibale Speed	0.686	0.65	0.58	0.512	0.449	0.392	0.34
	% Difference	0.0%	-2.0%	-5.8%	-11.0%	-16.4%	-22.2%	-27.5%
70	Constant Speed	0.7	0.677	0.629	0.585	0.546	0.512	0.469
	Varibale Speed	0.691	0.655	0.584	0.518	0.445	0.383	0.328
	% Difference	-1.3%	-3.2%	-7.2%	-11.5%	-18.5%	-25.2%	-30.1%
60	Constant Speed	0.715	0.69	0.64	0.601	0.562	0.526	0.469
	Varibale Speed	0.703	0.667	0.595	0.523	0.46	0.38	0.322
	% Difference	-1.7%	-3.3%	-7.0%	-13.0%	-18.1%	-27.8%	-31.3%
% Annual Operating Hours		0.9	3	21.2	26.4	25.8	19.2	3.5

VSD saves power even at Full load and more so at lower loads

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Medium Voltage Variable Speed Drives
Misconceptions & Fact Check

➢ MV Variable Speed Drives are expensive, with un-attractive payback	➢ MV-VSD costs and size, both have reduced with improved technology and its time to evaluate the payback
➢ District Cooling Plants always operate at Full Load Conditions	➢ DCP's seldom see full Delta T. As such, chillers are loaded between 60% and 80%
➢ Use for Thermal Storage means the chillers will always be operating at full design load.	➢ Again, limited by the low Delta T. Also, Thermal Storage Tank is always charged at off peak conditions and hence at low WB temp it will benefit most with VSD technology.
➢ Chillers must be evaluated for Full Load Efficiency at "Design" Conditions	➢ "Real" World conditions will always see reduced ECWT's and lower loads. Off design performance of Chillers is critical.

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Case Study

Annual Utilities Cost

20,000 TR Plant

Annual Water and Electricity Cost Comparison for a 20,000 TR Plant with following Options

OPTION 1
Normal Full Load Efficiency
4 x 5,000 TR series pair
@ Full Load 0.658 ikW/TR

OPTION 2
Option 1 + VSD
4 x 5,000 TR series pair
@ Full Load 0.691 ikW/TR

OPTION 3
High Full Load Efficiency
4 x 5,000 TR series pair
@ Full Load 0.627 ikW/TR

Summary of Case Study

Description	Option1	Option2	Option3
	0.653 kW/TR	0.691 kW/TR	0.627 kW/TR
	Constant Speed	Variable Speed	Constant Speed
	Normal Efficiency	Standard Efficiency	High Efficiency
	Normal Pressure Drop	Option 1 + VSD	Low Presure Drop
Annual Cost of Utilities (AED '000) as of Nov2016			
Chillers	21,950	19,900	21,770
Primary Chilled Water Pump	2,110	2,110	1,770
Condenser Water Pump	6,382	6,382	5,827
Total Energy Cost	**30,442**	**28,392**	**29,367**
Total Water Consumption	8,137	8,034	8,128
Total Cost of Utilities	**38,579**	**36,426**	**37,495**
Budgetary Initial Cost (AED '000)			
Price of Chiller	19,925	19,925	23,900
Price of Solid State Starter	2,540		2,540
Price of Variable Speed Drive		8,257	
Total Initial Cost	**22,465**	**28,182**	**26,440**
Additional Cost of VSD (Compared to Option3)		1,742	
Saving in Annual Cost of Utilities (Compared to Option3)		1,069	
Simple Pay back period in years		**1.63**	
Costs common among Options (Secondary Pump and Cooling Tower) not considered for comparison			

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Medium Voltage Variable Speed Drives

Selection Suggestions

MV VSDs have an internal transformer irrespective of incoming voltage and output voltage.

- Eliminate external transformer.
- Select output voltage to allow compact one piece drive.

MV VSD Application Suggestions					
Incoming Voltage	Specified Motor Voltage	VSD In Voltage	VSD Out Voltage	Motor Size	Remarks
New Projects					
11000	3300	11000	3300	Upto 2250 HP	Eliminate External Step Down Xmer
11000	11000	11000	3300	Upto 2250 HP	
11000	3300	11000	4000	2500 HP	For Use of Next Gen Compact VSDs
11000	11000	11000	4000	2500 HP	
Retrofit Project with VSD compatible motor					
11000	3300	3300	3300	Upto 2500HP	Using existing step down Xmer
11000	3300	11000	3300	Upto 2500HP	Remove existing Xmer to save losses
11000	11000	11000	11000	Upto 2500HP	
Retrofit Project with VSD incompatible motor (motor needs replacement)					
Treat as if a new proejct					

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Now that we have VSDs

How do we sequence the plant so as to operate chillers at their the Best Efficiency (COP) ?

Sequencing for Best Year-round COP

The answer to the Big Questions is simple and straight forward for **Constant Speed Drive Chillers**.

- For best COP, the Chillers should be made to operate at **near full load**, as far as possible.
- So, Sequence in a way that we run **just enough quantity** of Chillers to meet the Demand Load.
- This is extended to **pumps as well** along with the chillers and thus we run lesser water quantity in the primary loop and run fewer pumps

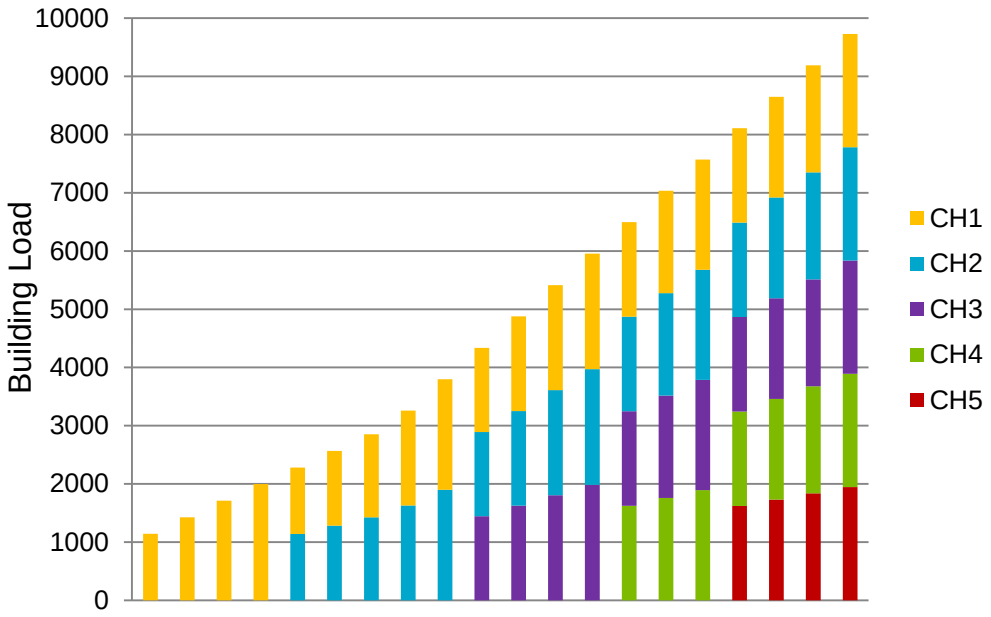
And …….this is the traditional **Load Based Sequencing**

Traditional Load based Sequencing

Consider:

- 10,000 TR Chiller Plant
- Qty (5) 2000 TR chillers piped in parallel
- Dedicated auxiliaries*
- Typical Load Line
- Year round operation - 24H/7D

Facility Load (%)	Chiller Systems Operating	Chiller Load Range (%)
100	5	100-80%
80	4	100-75%
60	3	100-65%
40	2	100-50%
20	1	100-10%



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Energy Based Sequencing

Consider:

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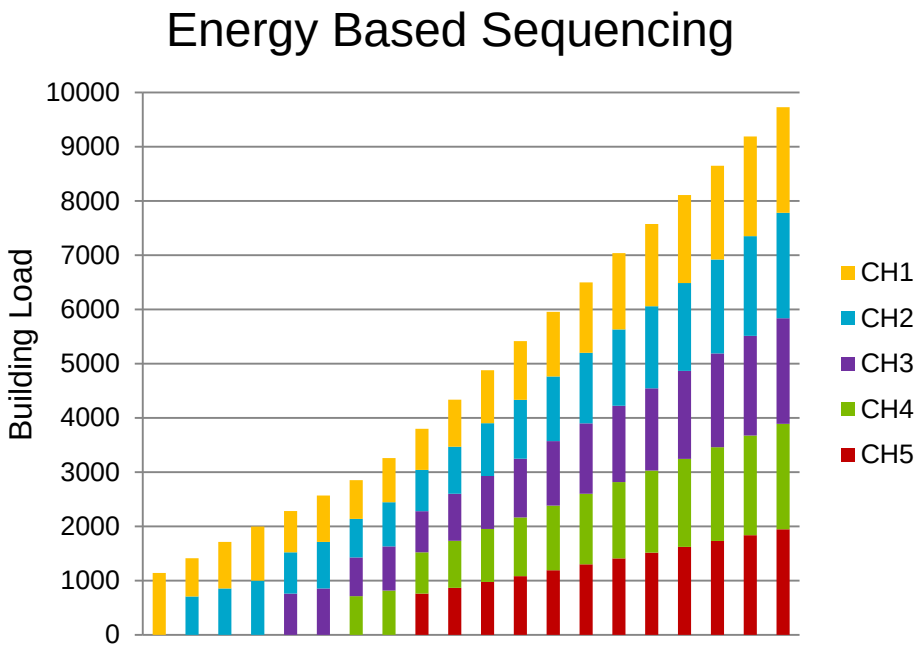
- Dedicated auxiliaries*
- Typical Load Line
- Year round operation - 24H/7D

Facility Load (%)	Chiller Systems Operating	Chiller Load Range (%)
100	5	100-81%
80	5	75 - 65%
60	5	60 - 43%
40	3 - 4	43 - 35%
20	1 - 2	50 - 35%



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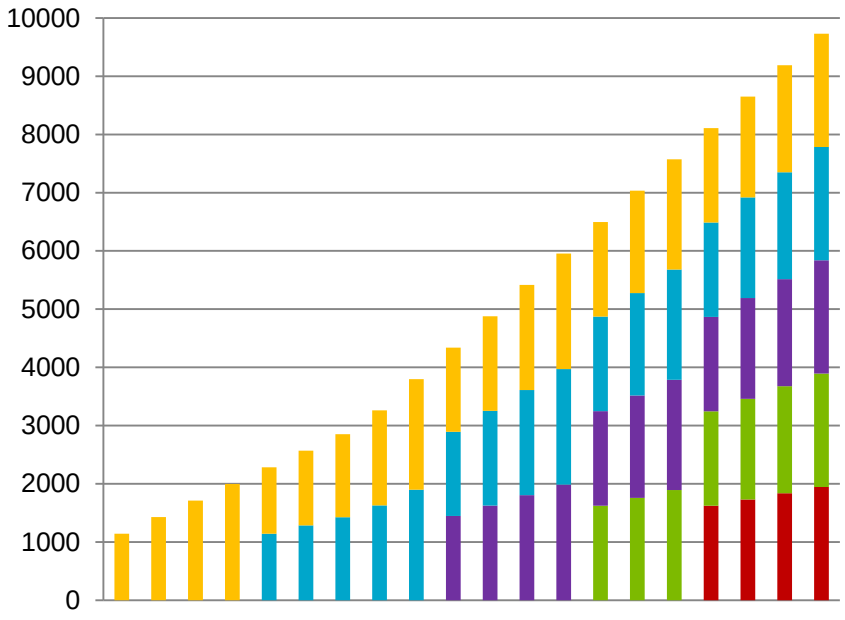
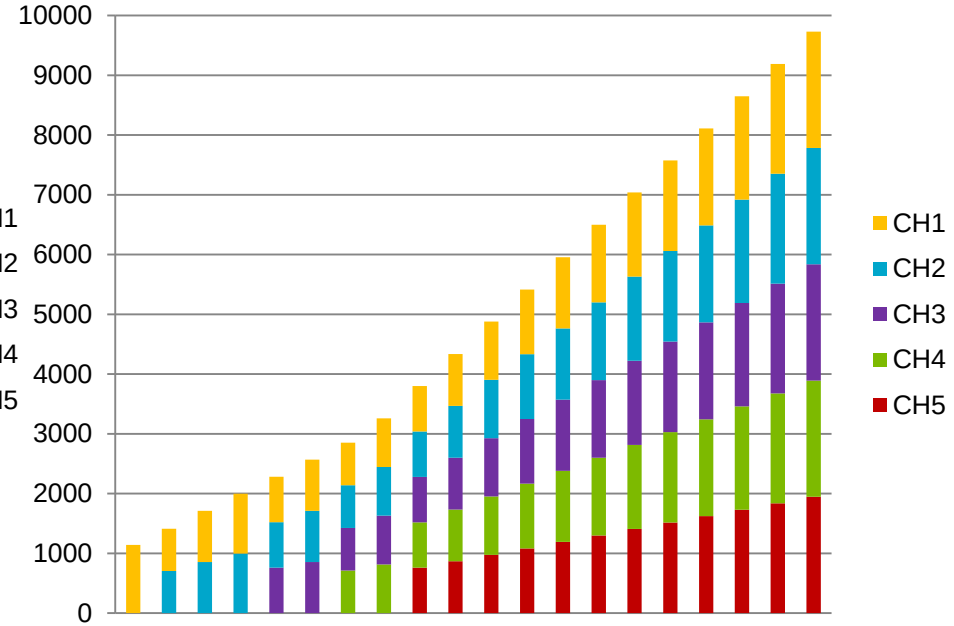
Energy Based Sequencing

Load Based Sequencing



- **Multiple Chiller plant piped in parallel**
  - Sequence based on return water temperature
  - Split the load equally among fewest number of chillers to satisfy the load

Energy Based Sequencing



- **Multiple Chiller plant piped in parallel**
  - Keep chillers on line and in part load operation for as long as possible as cooling load decreases
  - Turn on and off chiller systems based on energy consumption

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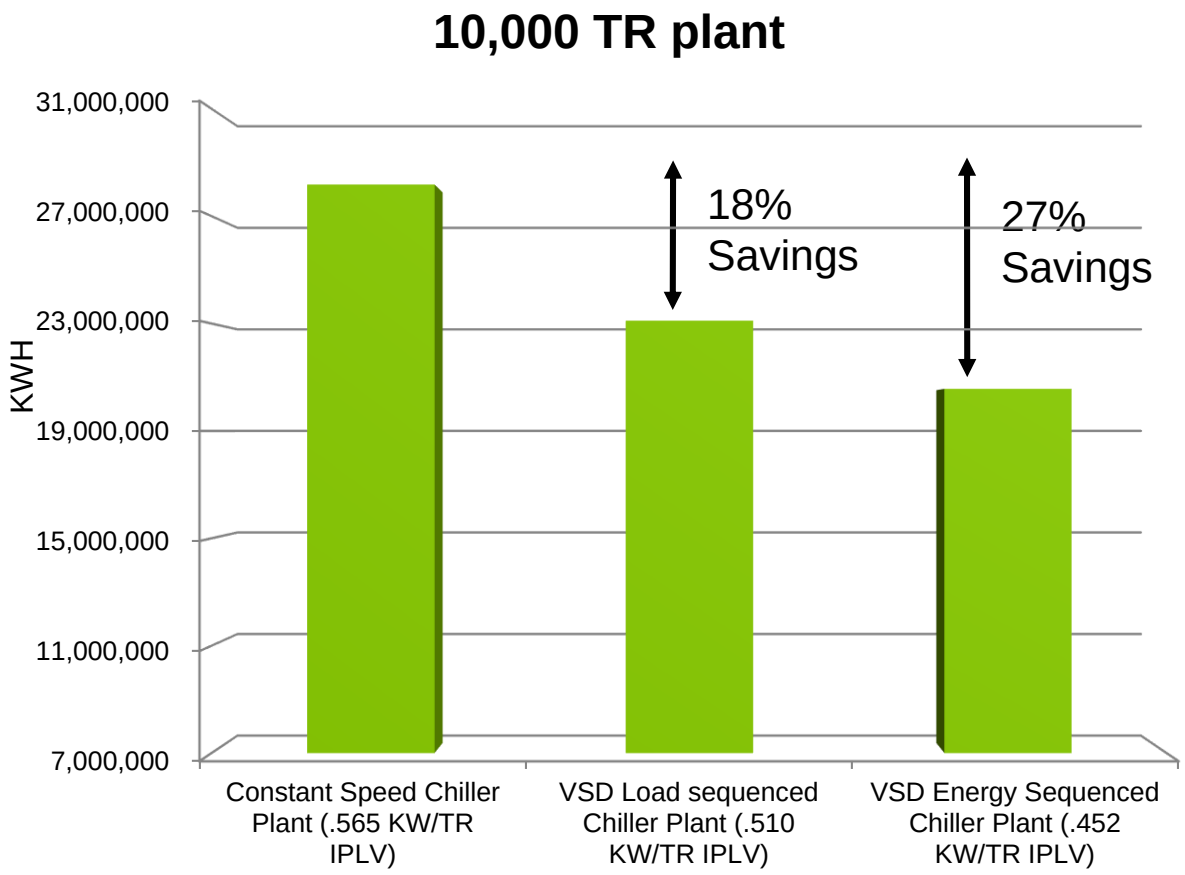
Energy Based Sequencing



49.7 Million Ton Hours

At $0.10/KWH

Annual Savings $600,000

Energy Based Sequencing Enhances the Savings of VSD chillers

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Energy Based Sequencing

Fantastic!...We saved so much in Chiller Energy…..

but, What about the pumps?

Shall we end up running more pumps than required.

Yes, you will….

But, when you combine it with **Variable Primary Flow (VPF),** you will actually save power.

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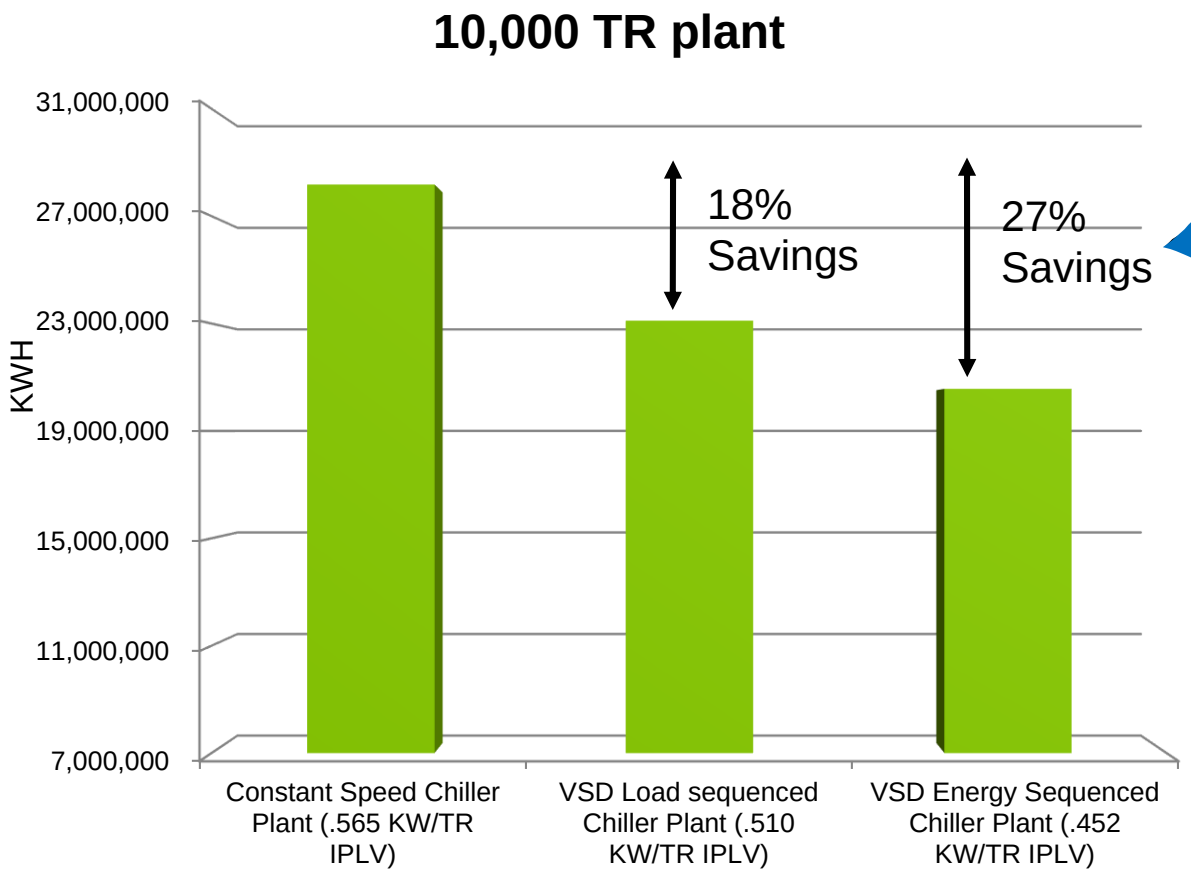
Bringing together the potential of Variable Speed Chillers & Variable Primary Flow pumping



With VPF, the savings can be further enhanced to in excess of **30%.**

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Bringing together the potential of Variable Speed Chillers & Variable Primary Flow pumping

…..And we all have been using it for so many years already.

The best technologies are inspired by Nature.

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