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Aging Gracefully:

Thermal Energy Storage coupled with Turbine Inlet Cooling

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INTRODUCTION – THE NEED FOR, AND VALUE OF, STORAGE

Most systems, whether in nature or man-made, incorporate some form of storage as a useful or necessary element. Examples include:

- organs in the body of humans and animals, such as the stomach, spleen, bladder, and brain,
- domestic water storage and wastewater storage tanks in a municipal water district,
- the fuel tank in your car,
- the battery in your laptop computer and cell phone,
- the water tank in your home's hot water heater, and even
- the ice cubes in your cold drinks.

The electric power grid (as well as microgrids) also benefits greatly from having storage. However, it has long been a challenge, and is increasingly important, to provide grid storage for several reasons:

1. The expanded use of air-conditioning has driven the growth in peak power demand, while widening the gap between peak and base-load demand.
2. Time-of-day differentials have risen in the power plant fleet's marginal heat rates, emissions, and electricity cost and value.
3. Short-term temporary back-up power is needed for unexpected interruptions in grid power.
4. And now, there is the rapidly expanding deployment of renewable power resources (wind and solar) which are highly intermittent and even out-of-phase with the demand for power.

With relatively little storage in the grid now, the problems have already become quite apparent:

- In Texas, there are nighttime periods when excessive wind power production added to the remaining base-load nuclear and coal power generation (which cannot economically be throttled) far exceeds total grid demand for power. As a result, short-term pricing of electric energy plummets as low as negative $0.10/kWh on many nights, while the pricing explodes to several dollars per kWh during high demand daytime periods, when wind power generation is typically low.
- In Nebraska, also related to excessive nighttime production of wind power, electricity pricing has been as low as negative $0.20/kWh.
- In California, negative energy pricing has also become common due to high levels of intermittent solar power and the resultant "duck curve" of the electric grid.

Data from the Electric Reliability Council of Texas (ERCOT), which manages the Texas electric power grid, has illustrated that at the time of day when the electric grid is experiencing its peak demand for power, wind power assets are very typically producing a scant 20% of their nameplate ratings. In the summer of 2017, ERCOT experienced a record instantaneous peak demand of approximately 70,000 MW. At that time, the ERCOT grid had connected wind power plants with a total nameplate capacity of roughly 23,000 MW. However, at the time of peak demand, the actual output of all the connected wind power plants was less than 600 MW, or only about 2.5% of their rated capacity. Essentially, in spite of all this mandated and expensive, tax-payer-subsidized renewable power plant capacity, it failed to yield any significant reduction in the need for conventional power generation assets.

Thus, a massive application of Energy Storage is necessary in order to take full advantage of existing, intermittent renewable power assets, and to justify the continued growing implementation of yet more such renewable power. But how is that Energy Storage element best added to the grid?

TURBINE INLET COOLING (TIC)

Gas Turbines (GTs), or more broadly Combustion Turbines (CTs), being constant-volume machines, inherently have a reduced mass-flow, and thus a reduced power output, at times of hot weather when air densities are reduced. Depending on the specific CT model and on the ambient air temperature, these output reductions can be as much as 10 to 25% below the standard (ISO) rated output, occurring precisely at those times when power is at greatest demand and has its highest value. Also at those high temperature times, heat rate or specific fuel consumption of the CT (Btu/kWh) can be negatively impacted by several to ten percent. Cooling the ambient air to a lower temperature as it enters the CT (commonly referred to as “T2”) can recover all that lost power and efficiency, or produce even more if the air is cooled to a T2 below the ISO temperature of 15 °C (59 °F).

The various technologies in common usage providing Turbine Inlet Cooling (TIC), include:

- evaporative cooling, which can entail
    - wetted media,
    - inlet fogging, or
    - fog overspray or wet compression;
- chiller-based cooling, which can use
    - electric motor-driven chillers,
    - steam turbine-driven chillers, or
    - heat-driven absorption chillers; and
- chiller-based cooling using (Thermal Energy Storage) TES, which can be
    - ice TES,
    - chilled water TES, or
    - low temperature fluid TES.

Hybrid solutions are also possible. Each TIC technology offers advantages and limitations, specific to any given application. The website of the Turbine Inlet Cooling Association (TICA), www.TurbineInletCooling.org, provides a thorough discussion and details of TIC options, benefits, examples, and much additional information, beyond the scope of this paper.

Evaporative TIC

These technologies are generally the least capital intensive ones. However, inlet evaporation limits cooling to temperatures slightly above the ambient wet bulb temperature, thus limiting power enhancement, especially during weather conditions that are hot and humid, which often are the conditions during which grid power demand is at its peak and has the highest value.

Chiller-based TIC

These technologies can achieve maximized cooling of the inlet air, down to a T2 below ISO values, for maximized enhancement of CT performance. However, they are fairly capital intensive, though unit power costs ($/kW) for the TIC are below those of non-cooled Simple Cycle or Combined Cycle CT power plants. Also, the chiller plant operation consumes a significant parasitic power consumption of electricity (and/or steam), thus reducing the net power enhancement of the power plant output.

Chiller-based TIC with TES
This solution also provides the ability to maximize the cooling of the CT inlet air to a T2 below ISO values, for maximized CT performance enhancement. Furthermore, it also provides a component of Energy Storage which, although adding some complexity and space requirements, reduces the parasitic power loss during peak demand periods, while also offering a reduction in the net capital cost of the overall TIC installation. It is this version of TIC, which we shall now explore further, as it often offers dramatically attractive solutions not only for low unit capital costs of power generation (in $/kW), but also minimized unit capital costs for multi-hour utility-scale Energy Storage (in $/kWh).

THERMAL ENERGY STORAGE (TES)

Thermal Energy Storage (TES) can store heat or cooling. The thermal energy can be stored in a material medium as a change in temperature (sensible heat storage) or as a change in phase (latent heat storage).

- Hot TES applications commonly use sensible heat storage in hot water, as well as in hot oil, hot rocks, concrete, ceramics, or molten salt.
- Cool TES applications commonly use either:
    - latent heat storage in ice (or in an alternative Phase Change Material or PCM), or
    - sensible heat storage in water (or in an alternative Low Temperature Fluid or LTF).

"Chilled water and hot water stratified thermal storage is the world's most viable storage technology."

- *George Berbari*, founder and CEO of DC PRO Engineering, Sharjah, UAE (*District Cooling and Trigeneration Summit*, 2016, Riyadh, Kingdom of Saudi Arabia)

For purposes of this discussion, we focus on sensible heat storage as thermally-stratified Chilled Water TES, as it benefits from an inherent and dramatic economy-of-scale, making it the most applicable TES technology for large-scale storage of cooling (and thus for utility-scale storage of the electricity consumed in cooling). This can be stored cooling either:

1. on the demand-side of the electric utility grid (for air-conditioning or process cooling) or
2. within the supply-side of the grid (for Turbine Inlet Cooling of Combustion Turbine power plants).

Chilled Water (CHW) TES
Thermally-stratified CHW TES employs a large insulated storage tank, filled with water at all times. The lower portion of the tank holds a zone of cool, relatively dense ("supply") water, while the upper portion of the tank holds a zone of warmer, less dense ("return") water, with a narrow band between those two zones containing the temperature gradient or thermocline. The two distinct temperature zones are kept from mixing through the use of flow diffusers at the top and bottom of the tank which slow the incoming and outgoing flow of water in the tank, to a degree that the density differences between the two water zones is adequate to maintain their separation. During off-peak periods of low cooling loads or low electric grid power demand (usually at nighttime), warm water is removed from the upper zone of the tank, cooled in a chiller plant, and returned to the lower zone of the tank, causing the thermocline to rise as the TES tank is charged. During on-peak periods of high cooling loads or high electric grid power demand (usually in daytime), cool water is removed from the lower zone of the tank, sent to the cooling loads, and returned to the upper zone of the tank, causing the thermocline to fall as the TES tank is discharged.

Even in relatively small applications, CHW TES provides a competitively low, installed unit capital cost. And as TES capacity increases, the unit costs drop dramatically. The examples in Table 1, each of which is a recent installation (from 2013 through 2018), are examples of large TIC applications.

Table 1 – Installed Unit Capital Costs of CHW TES

End-use Type - Location	Storage Capacity thermal (ton-hrs)	 electric equiv. (MWh)	Installed Unit Cost of TES Tank ($/kWh)
Turbine Inlet Cooling - Texas	144,000	86.4	53
Turbine Inlet Cooling - Virginia	267,800	160.7	24
Turbine Inlet Cooling - Virginia	268,641	161.2	27

The most significant factor in the TES unit capital cost is the scale of the installation. But many other factors impact the unit cost as well, including tank configuration, site & soil conditions, project labor requirements/rates, the energy consumption (kW/ton) of the chiller plant equipment, and quite importantly, the chilled water supply-to-return temperature difference (with a larger temperature difference resulting in a smaller, less costly tank for a given ton-hour capacity).

Cool TES is not only an effective means to reduce operating energy costs (by shifting electric use from on-peak to off-peak times and by reducing on-peak electric demand), but also can save substantial capital costs (when TES is implemented in lieu of otherwise necessary investments in conventional, non-TES cooling equipment). This is because a non-TES chiller plant must have an installed capacity equal to the *instantaneous peak* cooling load on a peak design day (plus any spare capacity deemed necessary), whereas a chiller plant with TES only requires an installed capacity equal to the *24-hour average* cooling load on that peak design day (plus spare capacity). The economy-of-scale of CHW TES results in very low unit costs ($/ton of TES discharge) which can be well below the unit costs of conventional non-TES chiller plant capacity. As a result, in cases of: 1) new construction, 2) retrofit expansions, or 3) retirements/replacements of aging chiller equipment, the capital credit for avoided chiller plant capacity is more than the investment in CHW TES, resulting in a net capital cost saving by employing TES. In those cases, CHW TES provides necessary cooling capacity, but does so for a capital cost that is better than free, while also delivering the value of Energy Storage to the electric grid. Table 2 provides just a few representative examples of these dual (operating and capital) savings which have accrued from CHW TES use. The examples illustrate a variety of types of end-use, locations, and climates, in both new construction and retrofit expansion situations. Each TES project shows tens or hundreds of MWh of equivalent stored electric energy as well as initial net capital cost savings in the millions of dollars, with the values rising with the capacity of the TES installation. The final, largest example is a TIC application.

Table 2 – Examples of Stratified CHW TES Savings

End-use Type - Location	TES project timing & type	Storage Capacity thermal (ton-hrs)	 elec. equiv. (MWh)	TES vs. Non-TES Chiller Plant approx. annual operating saving	 approx. initial capital saving
University campus - WA	1993 retrofit	17,750	13	$ 260,000/yr	$ 1,500,000
District Cooling - Portugal	1997 new	39,800	28	$1,160,000/yr	$ 2,500,000
University campus - Alberta	2005 retrofit	60,000	40	$ 600,000/yr	$ 4,000,000
Automotive R&D - MI	1990 new	68,000	50	>$1,000,000/yr	$ 3,600,000
International airport - TX	2002 retrofit	90,000	60	$2,000,000/yr	$ 6,000,000
District Cooling - FL	2003 new	160,000	120	>$ 500,000/yr	>$ 5,000,000
Turbine Cooling - Saudi Arab.	2005 retrofit	192,800	290	>$2,000,000/yr	>$10,000,000

TES COUPLED WITH TIC

TES of various types (ice, chilled water, and low temperature fluid TES) has all been employed in TIC installations, all achieving positive results. However, chilled water (CHW) TES has become the most common TES choice for TIC systems in the past 25 years. This is because CHW TES provides the following advantages versus other TES options:

- the most economy-of-scale, making it a particularly good choice for large utility-scale applications,
- simplicity of design and operation,
- the highest energy efficiency of the TES options, and
- storage supply temperatures down to 39 to 40 °F, adequately low to achieve the desired minimum T2 temperature (of 45 to 55 °F) for almost all TIC applications.

TES can be configured in numerous ways, as best suited for particular applications.

- Daily versus Weekly TES cycles:
    - Daily configurations are designed for TES to be fully charged and discharged on a 24-hour basis, typically charging each night during low power demand periods and discharging each day during high demand periods. This is the almost universal approach for CHW TES.
    - Weekly configurations are designed for TES to be fully charged during an extended weekend period of low power demand, then partially discharged each weekday, and partially recharged each weekday night. Such configurations allow for a smaller capacity chiller plant, but require a much larger TES capacity, than are required for a comparable daily configuration. This arrangement saves capital cost only where the TES technology has a particularly high unit capital cost for the chiller plant (as is the case for Ice Harvester type TES); it is not typically appropriate for CHW TES.
- Partial versus Full TES load shifting
    - Partial Shift TES configurations provide the necessary cooling for TIC, during a high power demand period, through a combination of both discharging TES and operating chillers. During subsequent off-peak (low demand) periods, the chiller plant operates to recharge TES, with no TIC occurring. One common partial shift system is a 24-hr Load Leveling TES which meets design day loads with a minimum capacity (and minimum cost) chiller plant operating fully loaded around the clock, coupled with a relatively moderate capacity TES; this results in a minimum total capital cost, but still has some significant parasitic power consumption subtracting from the net power enhancement during peak periods. Partial Shift TES is typically the economic design choice for applications where the period of high power value is 10 hrs/day or more.
    - Full Shift TES configurations provide 100% of the cooling from TES during the peak power demand periods. The chiller plant capacity (in tons) must be adequate to meet the desired 24-hr TIC load (in ton-hours), while only operating during a specified number of non-peak hours per day. Thus, the chiller plant capacity is greater (and more expensive) than for a partial shift design, while the TES is also larger and more costly; but the parasitic loads (other than some pumps) are completely shifted away from times of peak power demand and peak power value. Full Shift TES is typically the economic design choice for applications where the period of high power value is 6 hrs/day or less.
    - Note that on non-design days, when TIC loads are substantially less than on design days, a TES-TIC system designed for partial shift operation, can actually operate in a full shift mode.

But enough theoretical discussion. Let’s now explore some of the many real-world installations of TES-TIC, their benefits, and what we can learn from them.

CASE STUDIES OF TES-TIC

Actual case studies of TES-TIC illustrate its increasing and varied applications. They include TES-TIC applied for:

- new CT installations as well as retrofits to existing CTs,
- Simple Cycle CT plants, as well as CT Combined Cycle (CTCC) plants,
- various CT suppliers, including GE, MHI, Siemens, Solar, Turbomeca, and Westinghouse,
- small and large CT plants, from 3 MW to 3,000 MW, and
- varied locales and climates around the world.

Some of the examples of utility-scale installations using Chilled Water (CHW) TES-TIC are identified with pertinent project and performance data in the Table 3.

Table 3 – Examples of Utility-Scale Chilled Water (CHW) TES-TIC

Owner - Location	First Oper	TIC Type	Power Plant CT No. x Type	ISO Power (MW)	Air Temp Amb. (°F)	Air Temp T2 (°F)	TES-TIC Extra Power (MW)	TES-TIC Extra Power (%)	TES Load Shift Power (MW)	TES Load Shift Energy (MWh)
Brazos Elec Coop - TX	2009	r & n	4 x GE 7FA	1,120	95	50	101	11	15	77
Brazos Elec Coop - TX	2010	retro	1 x SW 501F	250	95	50	36	15	4	21
Calpine - TX	1999	retro	3 x W 501 D5	412	95	50	49	21	8	75
Colo Energy Mgt - NM	2009	new	2 x MHI 501FD2	188			19	10	7	39
Dominion - PA	2009	new	4 x GE 7FA	1,038	95	50	115	13	13	75
Dominion - VA	2011	new	2 x GE 7FA	560	95	50	60	14	7	52
Dominion - VA	2014	new	3x1 MHI CTCC	1,329	92	50	107	9	16	158
Dominion - VA	2016	new	3x1 MHI CTCC	1,329	98	46	123	10	20	196
Dominion - VA	2018	new	3x1 MHI CTCC	1,354			132	12	22	198
Duke Energy - FL	2017	retro	4 x (2x1) CTCC	1,912	95	50	220	13	40	240
Sempra - CA	2009	retro	2 x GE 7FA	566			50	12	5	27
SEC - Saudi Arabia	2005	retro	10 x GE 7EA SC	750	122	54.5	180	30	48	290
SEC - Saudi Arabia	2008	retro	40 x GE 7EA SC	3,000	122	50	720	31	213	1,065
Totals for 13 Projects	**1999-2018**		**81 CTs**	**13,808**			**1,912**	**9-31**	**418**	**2,513**
Average per Project	**retro&new**		**6 CTs**	**1,062**			**147**	**15.5**	**32**	**193**

Note that for these representative examples, hot weather power output enhancement for TES-TIC ranges from 9 to 31%, averaging 16%. And the average daily load shift from storage, per project, is 32 MW and 193 MWh.

TES-TIC AGING GRACEFULLY

TES-TIC Passes the Test of Time

There is an already long and growing use of TES-TIC, with some notable examples listed above in Table 3. Another early example, still in operation, dates back over 30 years to 1991 in Lincoln, Nebraska, when the local municipal electric utility, LES, retrofitted TES-TIC to an existing 65.2 MW Simple Cycle peaking plant (with one GE Frame 7B CT). The TES-TIC cools design-day ambient air from 101.5 °F to an inlet T2 of 40 °F, producing a net power output increase of 14.3 MW (a 27% net increase) for 4 hours/day.

Plant Owners Repeat the Installation of TES-TIC at Multiple Sites

The repeated use of any technology is a powerful testament to successful results and enduring customer satisfaction. An example of such repeated use of TES-TIC includes Dominion Energy, which completed five consecutive projects (one in Pennsylvania and four in Virginia) between 2009 and 2018, with details as follows:

1. On-line in 2009 and located in Fairless Hills, Pennsylvania, CHW TES-TIC was applied as a retrofit to the previously constructed (in 2004) 4x2 Combustion Turbine Combined Cycle (CTCC) Fairless Energy Power Station with four GE 7FA CTs and an ISO power output rating of 1,038 MW. The TES-TIC system provides a hot weather power output enhancement of 115 MW, representing a 13% net increase. The TES subsystem employs a single CHW TES tank (Photo 1) of 7.9 million gallons (143 ft Diameter x 65.75 ft High), storing 123,750 ton-hours at CHW supply/return temperatures of 39.5/66.0 °F and achieving a T2 of 50 °F. The hot weather peak load shift of the TES is approximately 13 MW for 6 hours, or 75 MWh.
2. On-line in 2011 and located in New Canton, Buckingham County, Virginia, CHW TES-TIC was applied to the newly constructed 2x1 CTCC Bear Garden Power Station with two GE 7FA CTs and an ISO power output rating of 590 MW. The TES-TIC system provides a hot weather power output enhancement of 60 MW, representing a 14% net increase. The TES subsystem employs a single CHW TES tank of approximately 5 million gallons, storing 78,710 ton-hours and achieving a T2 of 50 °F. The hot weather peak load shift of the TES is approximately 7 MW for 7 hours, or 52 MWh.
3. On-line in 2014 and located in Front Royal, Virginia, CHW TES-TIC was applied to the newly constructed 3x1 CTCC Warren County Power Station with three MHI 501GAC CTs and an ISO power output rating of 1,329 MW. The TES-TIC system provides a hot weather power output enhancement of 107 MW, representing a 9% net increase. The TES subsystem employs a single CHW TES tank of 8.92 million gallons, storing 232,000 ton-hours and achieving a T2 of 50 °F. The hot weather peak load shift of the TES is approximately 16 MW for 10 hours, or 158 MWh.
4. On-line in 2016 and located in Freeman, Virginia, CHW TES-TIC was applied to the newly constructed 3x1 CTCC Brunswick County Power Station with three MHI 501GAC CTs and an ISO power output rating of 1,329 MW. The TES-TIC system provides a hot weather power output enhancement of 123 MW, representing a 10% net increase. The TES subsystem employs a single CHW TES tank of 11.12 million gallons (145 ft Diameter x 90 ft High), storing 267,800 ton-hours at CHW supply/return temperatures of 39.0/78.2 °F and achieving a T2 of 46 °F. The hot weather peak load shift of the TES is approximately 20 MW for 10 hours, or 196 MWh.
5. On-line in 2018 and located in Emporia, Virginia, CHW TES-TIC was applied to the newly constructed 3x1 CTCC Greensville County Power Station with three MHPS M501 CTs and an ISO power output rating of 1,354 MW. The TES-TIC system provides a hot weather power output enhancement of 132 MW, representing a 12% net increase. The TES subsystem employs a single CHW TES tank of 11.47 million gallons (147.5 ft Diameter x 89.75 ft High), storing 268,641 ton-hours at CHW supply/return temperatures of 39.3/79.0 °F. The hot weather peak load shift of the TES is approximately 22 MW for 9 hours, or 196 MWh.

Photo 1 – 123,750 ton-hour (7.9 million gallon) CHW TES tank at Dominion's Fairless Hills, PA plant (Photo credit: CB&I / McDermott)

The five Dominion projects involve 15 CTs with CHW TES-TIC producing 537 MW of hot weather power enhancement (representing 9 to 14% net power increases). The TES subsystems account for a peak load shift of approximately 78 MW ranging for periods of 6 to 10 hours/day, or approximately 679 MWh of storage.

TES-TIC Earns Awards from the Power Generation Industry

For both 2015 and 2016, *Power Engineering* magazine bestowed its prestigious Project of the Year Award on a Dominion plant that incorporated TES-TIC:

- The 2015 Overall Plant of the Year award winner was Dominion's Warren County, Virginia plant. This was a new 1,329 MW 3x1 CTCC plant (with 3 MHI 501GAC CTs) using 23,700 tons of chiller plant capacity plus 237,000 ton-hrs of chilled water TES to cool design-day ambient air from 92 °F to an inlet T2 of 50 °F, producing a net power output increase of 107 MW (an 8% net increase) for 12 to 14 hours/day.
- The 2016 Natural Gas-fired Plant of the Year award winner was Dominion's Brunswick County, Virginia plant (Photo 2). This was a new 1,358 MW 3x1 CTCC plant (with 3 MHI 501GAC CTs) using 29,300 tons of chiller plant capacity plus 293,000 ton-hrs of chilled water TES to cool design-day ambient air even further, from 98 °F to an inlet T2 of 47 °F, producing a net power output increase of 123 MW (a 9% net increase) for up to 14 hours/day.

Photo 2 – Dominion's Brunswick County, Virginia CTCC Plant with TES-TIC
(Photo credit: Fluor)

Low Installed Unit Capital Costs for TES-TIC

Installed unit capital costs for large CTCC power plants have typically ranged from $800 to $1,000/kW, based on their rated ISO power outputs; but when corrected for actual hot weather operating conditions (when power is most in demand and most highly valued), the de-rated outputs yield true unit costs of $900 to $1,200/kW. By contrast, large applications of chiller-based TIC systems (but not using TES) have typically had installed unit capital costs for the power enhancement that are only about half of those values for CTCC plants without TIC; the actual unit costs of TIC are dependent upon many factors including: the actual CT model's performance variation versus inlet temperature, the ambient dry & wet bulb temperature, the cooled T2 (inlet air temperature), and whether the TIC installation is executed along with a new CT installation versus as a retrofit to an existing CT. Furthermore, large chiller-based TIC systems that do incorporate TES have typically had installed unit capital costs even lower than the TIC systems without TES; actual unit costs vary dependent upon the factors listed above, as well as on the configuration of the TES system (for "full shift" or "partial shift" of the chiller operation during peak hours) and on the hours/day of TES use.

Because a TES-TIC system typically utilizes a reduced chiller plant capacity, the combined costs for the TES tank and the smaller chiller plant are typically less than for a non-TES chiller plant, only. The result is a reduction in net capital cost, which means that the incorporation of TES occurs at a negative cost, i.e., a net capital cost saving, while simultaneously providing an increase in peak power enhancement (by minimizing the parasitic power consumption of the chiller plant during periods of peak power value) plus realizing the benefits and value of Energy Storage.

SUMMARY AND CONCLUSIONS

Summary

- Energy Storage is increasingly important to the electric power grid and the continued expansion of renewable power resources.
- Turbine Inlet Cooling (TIC) of many types is a mature technology which benefits the hot weather performance and economics of Combustion Turbine (CT) power plants
- Thermal Energy Storage (TES) of many types is another mature technology which provides multi-hour Energy Storage, and compares favorably to batteries and other Energy Storage technology options in terms of performance and cost.
- Chilled Water (CHW) TES is often coupled with TIC for utility-scale applications, in which it maximizes power output during peak demand periods and reduces net unit capital cost ($/kW) of the incremental power generation.

Conclusions

1. TES-TIC is a long-proven technology, with one owner's installation dating from 1991, with over 30 years of continuous service.
2. In 1902, the Packard Motor Car Company began using its slogan: "Ask the Man Who Owns One" as a powerful expression of confidence in performance and value. Regarding TES-TIC "aging gracefully" we can similarly state "Ask the Folks Who Own *(MORE THAN)* One." A representative example is one power plant owner which has deployed large CHW TES-TIC systems in five consecutive projects over a decade of time, demonstrating its satisfaction with the technology's successful performance and economic value.

ACKNOWLEDGEMENTS, REFERENCES, AND BIBLIOGRAPHY

- Andrepont, J.S. and Dixon, D.S, "An Alternative to Battery Storage: Thermal Energy Storage for Demand-Side and Supply-Side Applications", PowerPoint at POWER-GEN Connect, June 2021
- CB&I (A McDermott Company) – www.cbi.com
- Liebendorfer, K.M. and Andrepont, J.S., "Cooling the Hot Desert Wind: Turbine Inlet Cooling with Thermal Energy Storage (TES) Increases Net Power Plant Output 30%", ASHRAE Transactions, Vol 111, Part 2, 2005
- Turbine Inlet Cooling Association (TICA) Experience Database – www.turbineinletcooling.org

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