On the Concept of Stable Conditioned Power From Solar

White Paper

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Background: Utility company generators work nearly continuously. These powerful generators are stable and well controlled to provide energy smoothly. Solar energy by its very nature is not. Solar electrical generating systems put energy into the grid only when the sunlight is available and that is generally less than 30% of the time in the course of a year. In the vernacular of electrical power generation, solar generators have an Annual Capacity Factor[1] of less than 30%.[2] But it is even worse than that. When sunlight is available it can be for very short bursts of time, unpredictable and quite sporadic. Conditioned power by definition is smooth and continuous. Spurious spikes in a grid can easily cause an instability resulting in complete and widespread blackouts. This is a very serious situation when solar or any other augmentation system is considered on a large scale. CENICOM solar technology has solved this difficult problem.

Energy Versus Power: As in the above topic, energy and power are terms intermingled in the same discussion which at times can cause confusion. Utility companies deliver energy not power. Energy is the commodity with which Utility companies receive revenue. The electrical bill is in "Kilowatt-Hours" and the gas bill is in "Therms" or Btu's all of which are measurements of the amount of energy used and have almost nothing to do with power. Power is similar to size (Kilowatts, Horse Power, etc.). A small boy is less powerful than a man. You may pay more, however, to keep the boy quiet than a resting man. The boy is delivering energy whereas the man is not. The real difference is their *capacity* to deliver the energy and, of course, the larger one has a much bigger capacity to deliver. Power is ability to deliver energy; energy is the capacity to do the work. Power is a measure of how much *energy* can be delivered in a period of time. Consider an intimidating large water tower several stories high. How much energy and how much power are there? Yes, the tower is potentially very powerful but drains its capacity through a syringe and not much work (energy) is being done. Have a breach in the tower thus releasing its energy in milliseconds and you have much work done (destruction—energy).

Cost for Installed Watt: Power companies are *sized* based on how much *energy* is required by their customers. Once known, then how *powerful* the equipment must be to supply the customers is determined. Energy usage is the initial consideration and then the sizing of the equipment is determined. Once done, then the cost of installing the equipment can be determined. Because a

[1] Annual Capacity Factor is the amount of hours an electrical generator is generating its energy divided by the number of hours in a year (365 x 24= 8,760 hours)

[2] Annual Capacity Factor for solar is between 25%-30% depending upon the geographical location.

large share of the cost will be the equipment itself and since the equipment is rated in terms of *power* rather than the energy it will deliver, a classical *figure of merit* for a plant is its cost per installed *watt* (power). But when sizing a solar electrical generating plant, this may become a misleading figure of merit because of the solar's implied Annual Capacity Factor (ACF). The result is in clever marketing as will be demonstrated in an analysis to follow.

Energy Usage: Energy usage is the amount of power by the amount of time the power is delivered. 1000 Watts of *power* (One Kilowatt) delivered in an hour is one kilowatt-hour (kWh) of energy. The utility company derives its revenue based on the energy used, not the power of the equipment that delivered the energy. Thus, you pay by the kilowatt-hour and not by the kilowatt.

Designing Solar Electrical Power Plants: Solar power plants should be analyzed in much the same way. That is, by how much energy is required. Because there are so many different ways to implement solar plants and ways to define their attributes, the industry has been struggling to find its own figures of merit. Solar power plants are still considered as *alternate* energy devices basically serving an augmenting role where classical figures of merit may not make much sense and again, may be misleading.

The Annual Capacity Factor and Clever Marketing: As previously defined, the Annual Capacity Factor (ACF) is basically the percentage of time a power generator will deliver its energy in one year. Example: A 6.0 Megawatt Generator working with a 76% capacity factor will deliver 6.0 Megawatts in approximately 6658 hours (.76 x 365 day per year x 24 hours per day). The amount of energy delivered is simply 6 MW x 6658 Hours or 39,948 MWh (Megawatt-hours). On the average, this works out to be a little over 18-hours of usage in a 24-hour day. Suppose that the energy requirement is only to be delivered for 6-hours a day each and every day. Six hours a day is a 25% capacity factor. In order to deliver the *same* amount of energy as before, the generator would have to be 3 times more powerful or would have to be 18 MW in *size*. Now for some clever marketing: suppose that the 6 MW generator sold for $600,000 and the 18 MW sold for $1,200,000 (twice the amount). The cost per installed watt would be 10 cents for the 76% ACF but only 6 2/3 cents for the 25% ACF. If the cost per installed watt were the deciding factor, the 18 MW system would be the clear winner. But the *revenue* would be the same because the amount of energy delivered would be the same. The 18 MW system would show a much poorer return on investment. Thus, the cost per installed watt cannot be considered alone as a figure of merit. In fact, cost per installed watt may indeed be misleading. Sizing is an important criterion when designing a power plant but it is more a dependent factor. The independent factor must always be what best serves the end user and that is the amount of energy ultimately delivered. Of course nothing was mentioned about whether the energy delivered was smooth and conditioned, which must also be considered as an important factor

Annual Capacity Factor and Solar Power Plants: In general, solar electrical power plants have no practical means of storage[3]. For this reason, the annual capacity factor for a solar plant is usually *fixed* at about 25-30% (the average amount of time the sun shines in a day in a particular region.). As just stated, boasting a lesser cost per installed watt is not only misleading but may just be the hook that the general public needs to lean toward solar plants unable to store their energy. But uncontrolled spurious solar spikes are dangerous. What follows is an analysis of a solar technology able to store its energy and deliver it conditioned anytime night or day.

Conditioned Power From a 6-MW Turbine-Generator via OG-5 Solar Thermal Technology

The company behind the CENICOM technology was recently asked to propose one of its systems to drive an existing 6 MW turbine generator set. The chief engineer after going through *several* tradeoff analyses concluded that the most efficient way to drive this output device was to operate it at its maximum rated power for no less than eight (8) consecutive hours at a time. His analysis was based upon actual hourly measured sun intensities. The system was configured (storage capacity determined) to meet this goal. As a result of this comprehensive analysis, the system provided full rated conditioned power for approximately 6658 hours during the course of a typical year or 76 percent of the number of hours in that year. The *fallout* of the simulation analysis was an ACF that serendipitously maximizes the reliability and maintainability of the rotating machinery.

Hours of Operation: 365 x 24 x 0.76 = 6658 hours

Energy Output: 6658 hours x 6,000,000 watts = 40 x 10^6 kilowatt-hours electrical energy

One CENICOM Output (based upon measured sunlight): 371 x 10^3 kilowatt-hours

Number of CENICOMS (To produce the 40 x 10^6 kWh): 4 / 3.71 x 10^2 = 108 CENICOMS or three (3) CENICOM Clusters (36 CENICOMS per cluster)

The Derived Figure of Merit: As a result of the above simulation, it has been determined that CENICOM systems are best configured to drive large electrical generating sets at a 76% ACF. This concept maximizes efficiency, maintainability and reliability of the large generating equipment. Based on the 6 MW example, CENICOM power plants are being sized to be one (1)-CENICOM Cluster for each two (2) Megawatts of *conditioned* power desired. The expected

[3] The exception to this is the CENICOM technology whose major feature is its ability to deliver conditioned (smooth) solar derived energy anytime night or day.

practical limit of ganging CENICOM clusters is 20 (720 CENICOMS) or a power plant size of 40 MW.[4]

Photovoltaic (PV) comparison: It is important to note at the outset of a comparison that PV arrays *do not store energy* and must be capable of delivering all of its energy only during sunlight hours and even spuriously at that. The published specification of such a PV array delivers approximately 216 kWh's of energy per year for each square meter of collection surface. This amounts to 1718 M^2 of collecting surface to deliver the *same* amount of energy as *one* CENICOM that needs only 650.3 M^2 of collecting surface. Immediately, the PV array requires 2.6 times the land area of a CENICOM. Note that such a PV array, at the very apex of a bright sun, is intercepting 1718 kW of solar power (1.0 Kilowatt of solar power impinges on 1.0 M^2 of collecting area). The published electrical energy delivered efficiency of this array is 8.45% meaning that machinery *must* be available to process these peak power loads of slightly over 145 kW. This machinery, however, would operate only 29.22% of the time[5]. The equivalent machinery for a single CENICOM needs only to be a 55.7 kW generator operating smoothly 76% of the time. Thus a PV array requires generating equipment 2.6 times as powerful (the same as the land area factor) but only operating 38% of the time that the CENICOM generators are operating. This is a significantly more costly and less efficient process and it is sporadic and thus dangerous.

To summarize, PV arrays require 2.6 times the land area, 2.6 times as powerful generating equipment operating only 29% of the time delivering uncontrolled spikes to the grid.

Cost per Installed Watt: Because a PV array will require 2.6 times as much power to deliver the *same amount of energy* as one CENICOM, the cost per installed watt becomes misleading. For instance, if the PV array cost was exactly the same as the cost for the CENICOM system, then the PV Company would boast that their cost per installed watt would be 2.6 times *less*. The more appropriate comparison is the cost for the energy delivered in a year's period of time, which must include the cost to install the system and the cost of land.

Grid Instability: Some time ago when alternative energy systems began augmenting the grid, the amounts were negligible compared to the grid's size. Now, when much larger alternative systems are being considered, their effect becomes more significant. In areas where grids are many and small, there is the possibility that the grid can become unstable when there are sporadic surges from these alternative systems. Grid surges present serious and dangerous problems and must be controlled, especially now that these alternative systems are evolving into much larger size. That is, the grids must be conditioned and

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[4] The crossover point where the percentage of losses through ganging begins to erode the percentage of energy delivered.

[5] This is determined by the energy delivered in one year using a 145 kW sized generator set, i.e. 371 x103 kWh/145 kW = 2559 hours or 2559/8760 = 29.2%

smoothed. The only solution to this problem is to make certain that any augmentation system is countered with an equivalent sized standby system. This solution almost makes no sense but must be required because the current augmentation systems proposed only deliver their energy when the wind or sun is available. Once again, the augmentation systems have no ability to ballast their output. If they *could* smooth themselves, standby systems would not be required.

The Value of Smoothing: There is *value* for smooth and conditioned power that must be determined when considering alternative systems. Value is placed on driving a turbine generator set at an attractive ACF. Value must be associated with the power generating equipment directly. Value must be placed on supplying the energy on demand on not just when the energy is available. Value must be placed on an alternative system that does not require standby systems. All told, this can easily amount to significant dollar savings over the life of the system. CENICOM technology possesses all of these attributes and thus can practically augment a grid, large or small without requiring specialized and costly controls. In fact, CENICOM technology is a practical *standby* solution in itself for those wind and PV projects already in place or underway.