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Solar Energy Application in a US Automotive Plant Feasibility Study

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Abstract: *This paper is devoted to analyze the procedures necessary to adapt Solar Power systems to industrial manufacturing facilities. While Solar Power has been in existence since the 1950s, its popularity is growing due to the negative impact carbon emissions impose on the environment as a result of coal generated electricity. Wide use of solar in industrial applications will grow this renewable to help reduce the overall costs by volume, and lead to affordability for residential use. An automotive components plant was used to provide a realistic approach of the process needed to evaluate the feasibility of integrating solar power.*

Keywords: Solar Photovoltaic Systems, facility and process demand loads, on grid and off grid configurations, sun exposure analysis.

1. Introduction

The effort in this paper is to conduct a feasibility study of integrating Solar Power with an Industrial Manufacturing Facility.
The implementation of Solar energy provides the following results [1, 2]:

a. Reduction in green house gas emissions caused by coal generated electricity.
b. Reduce the impact of global warming.
c. Increased competition in the market place for reduced energy costs.

Solar installations in the late 1970s were primarily residential or installations on a relatively small scale [3, 4]. Interest has grown in applying solar to industrial facilities; however certain practices must be studied since the power systems between residential and industrial are quite different.

A major difference between the power systems concerns the fact that residential utility feeds are typically 240 VAC, and an industrial utility feed can be 13.2 KVAC with transformers supplying a 480 VAC distributed system. Common market solar inverters have a maximum voltage of 480 VAC. Careful engineering is required to evaluate the industrial 480 VAC system in relation to the expected load distribution and the physical placement of inverters and solar panels.

There are advantages to manufacturing facilities that offer Solar. One advantage is the availability of flat rooftops where mounting and installation are cost effective and no additional real estate is required.
While there are excellent global resources and expertise with the use of Solar Photovoltaic Systems, help is needed for the end user to assist with understanding basic fundamentals of integrating a Solar system within their facility.

This study will use an automotive components production facility located in Michigan, USA.
The primary objectives of integrating a Solar System are:

a. Analyzing the sun-exposure levels and associated months of available power to establish a financial feasibility.
b. Determining the anticipated demand load for a new facility, or the average demand load for an existing facility.
c. Establishing on-grid and off grid configurations.

2. Sun Exposure Analysis

This analysis needs to be conducted in order to aid the customer in making the decision of investing solar power locally to their site. This is based on the 12 month cycle of sun-exposure levels, and the anticipated levels through each daily cycle during the month. Figures 1 & 2 illustrate examples of this analysis.

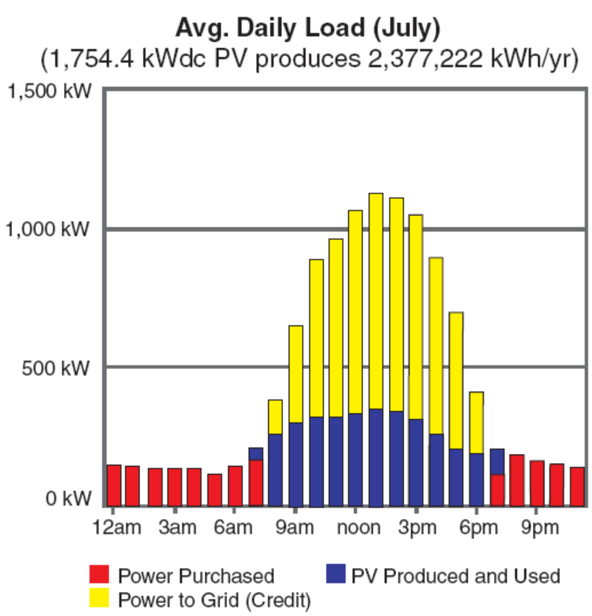

Figure 1: Average daily load for the month of July, where peak exposure is expected as tabulated by Inovateus Solar.

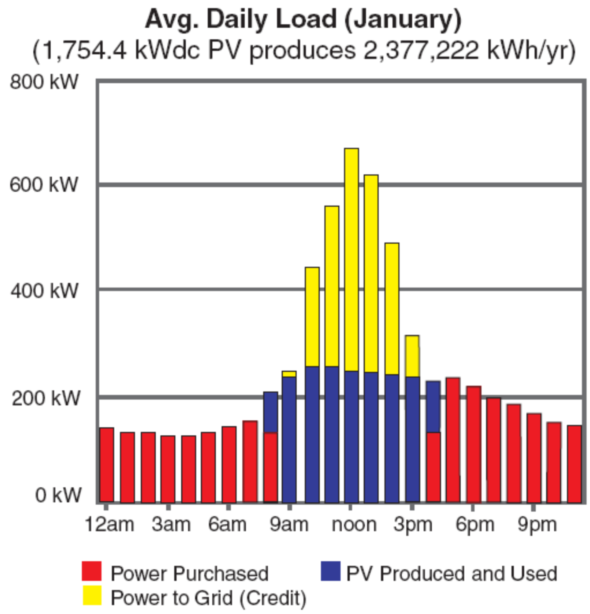

Figure 2: Average daily load for the month of January, where the least amount of exposure is expected as tabulated by Inovateus Solar.

The above illustrations show where there may be opportunity to feed power (credit) into the utility grid. This would be an example of when the Solar power exceeds the facility demand. This case study was unable to take advantage of this credit due to the fact where the physical roof footprint did not allow the Solar capacity to exceed the production demand load.

These exposure levels equate to the amount of power the customer can expect. The supplemental solar power anticipated from the above calculated over 1 year is the relation of investment return as shown in the following sections.

3. Production and Facility Load Estimations

The overall anticipated loading of the facility needs to be determined. The average demand process load of the production equipment and the facility power needs to be established to determine the power capacity of the facility. Process power is derived from:

- the actual running load of the tooling equipment,
- the production rate,
- the hours of production and number of shifts.

Care must be taken to not use Full Load Amperage loads as these values could inflate the actual load while running production

Facility power is derived from:

- air houses and associated chillers,
- air compressors,
- building lighting,
- non-production operations such as offices.

The duration of production and number of shifts needs careful consideration and has an influence of taking advantage of the solar power. An example is a facility that requires 3 shifts of production. Will the customer require batteries for storage of power, or is the power from the utility company acceptable during night periods? Although the night shifts demand for some facility items will be reduced, such as chillers for tempered air, the total power for the facility will be reduced while the sun exposure levels are none.

The financial, sun-exposure, and facility power requirement studies are likely to be conducted concurrently during the initial phase of the analysis.

The customer can consider some advantages of the solar system such as where warmer climates require tempered air, those periods will have higher sun exposure levels, accommodating the increase in demand. Conversely in the cooler climates, where snowfall is less likely with colder temperatures, the exposure will be higher during those periods to accommodate fans for heating.

While the modelled system in this study had a power capacity of 16 MW, an actual consumption may be approximately 5 to 6 MW based on a similar factory's usage.

4. Solar Panels Placement Evaluation

The available space of installing solar panels is a critical factor in establishing the amount of available solar power. In this study, the roof has been chosen as the preferred location to install solar panels. The roof is 607,400 square feet; however after taking into account air houses, ventilation stacks, and shading there is approximately 486,000 square feet to install solar panels.

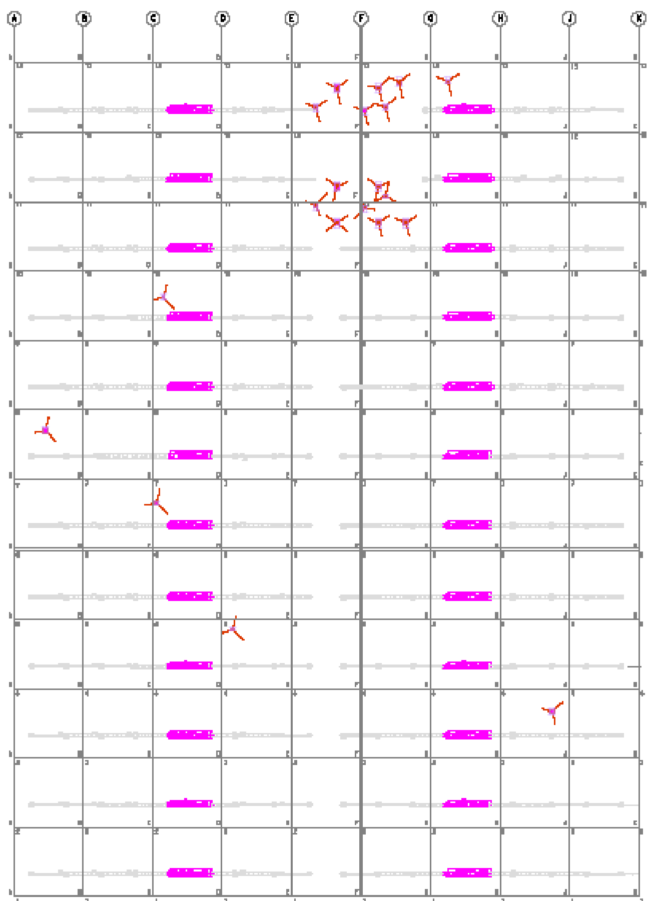

Figure 3: Roof location and interferences sample to estimate solar panel placement considerations. Each bay is 75 feet x 75 feet.

Depending on the type of solar panels, the weight and associated structure to support the panels may need careful consideration. Kip loads may need to be calculated to assure the addition of panels will not create safety concerns with the support of the roof.
Some manufacturing facilities may utilize overhead conveyance systems which are typically supported from the buildings'' internal support steel and can decrease the available loading to the roof. In this study, we are using light weight Uni-Solar panels which use a simple adhesive backing that can be applied to the roof surface. This does not require any special support structures.

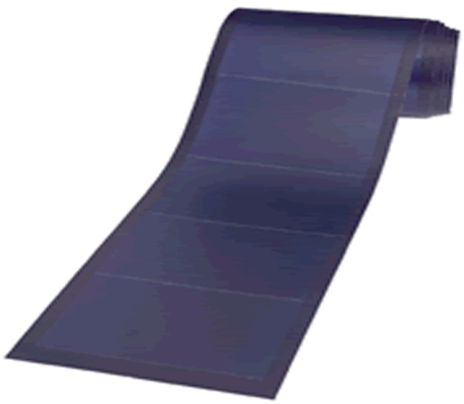

Figure 4: Uni-Solar adhesive back solar panel.

Figure 5: Uni-Solar installation, Long Beach Convention Center.

Another consideration with cost and installation implications are panels which require physical mounting to the roof. These can likely cause hole penetrations attributing to leaks. This may not occur for several months after the installation contractor has left the site. In a typical manufacturing facility that utilizes powered bus ducts, water damage can be detrimental and cause unexpected downtime.

5. General Power Configuration

The coordination of panel placement and inverter configurations in relation to the power system will have an impact on the cost, performance, and power balancing of the system. The electrical one line diagrams in conjunction with the bus duct layout need to be analyzed to determine the anticipated power balancing.

To estimate a rough order of this magnitude, the exact configuration will not be designed. However, an estimate of the anticipated power requirements is determined. The customer should be briefed on the various configuration options that they can expect in the final design. The final design will examine the power loading for each of the secondary (480 VAC) power systems, where the inverters will be configured in parallel.

The following figures 6 and 7 below illustrate an example of coordinating the one line electrical 480 VAC secondary system with the physical location of bus ducts.

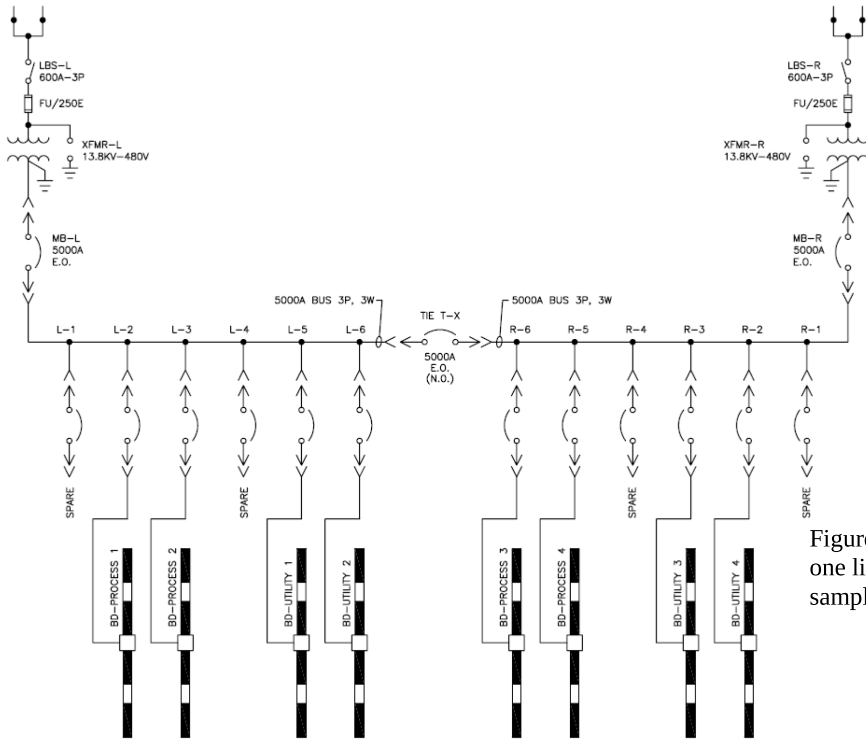

Figure 6: Electrical one line drawing sample.

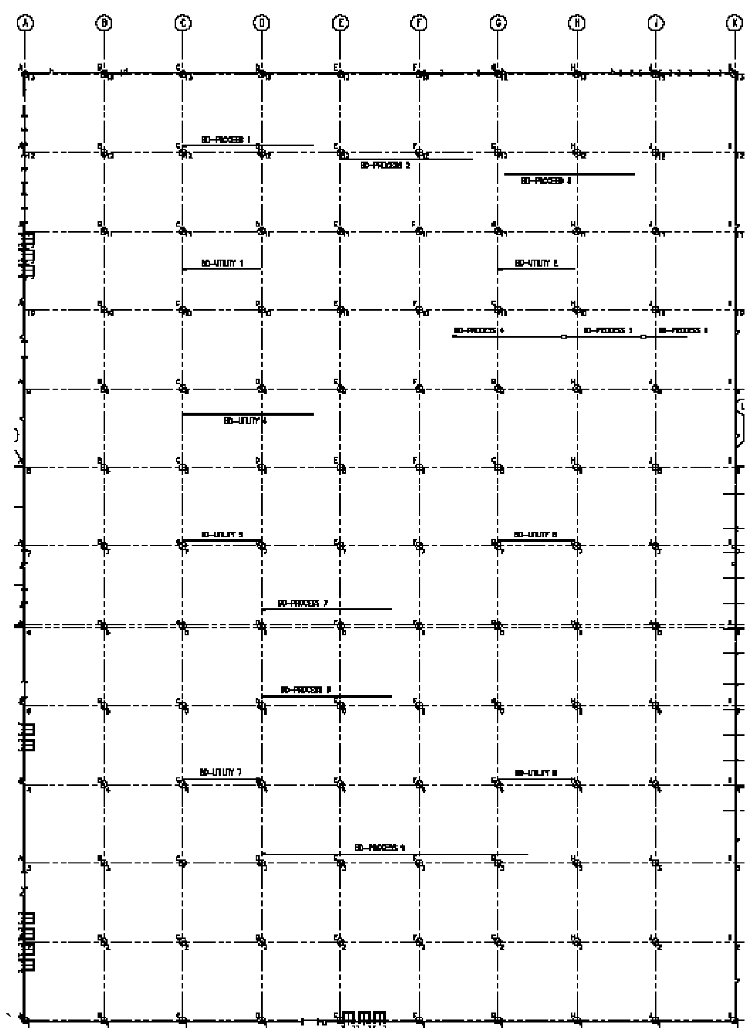

Figure 7: Bus duct locations sample.

The following block diagram shown in figure 8 below illustrates a section of solar panels feeding into the 480 VAC secondary system in a parallel manner.

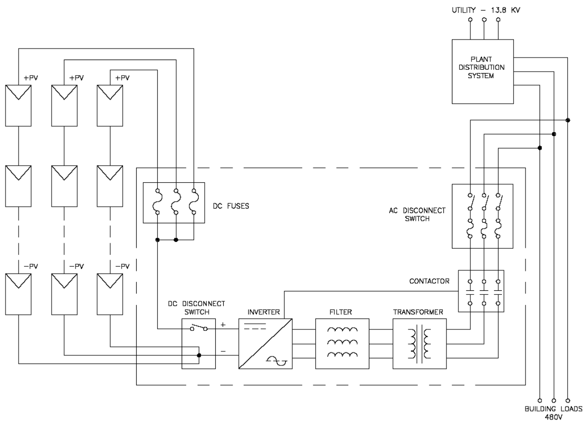

Figure 8: Solar block diagram modeled from Solectria Renewables [5] inverter illustrating Solar integration with the secondary (480 VAC) plant power system.

Utilizing the above sun exposure level averages, production and facility load estimations, solar panels placement estimation, and the general power configuration, a feasibility study and associated costs can be established.

6. Initial Financial and Technical Overview

Facility:	Automotive Components Plant
Plant Data:	607,500 Square Feet
	16 MW Anticipated Calculated Power
Components Plant (reference) Average Hour Usage 2007:	5 to 6 MWH
Estimated Available Roof Space:	486,000 Square Feet
Desired Solar Power Capacity:	1.4 MW
Solar Cost Materials And Labor:	$7.00 per watt
TOTAL INVESTMENT:	**$ 9,870,000.00**
Pay back period:	**13 Years**
Based on Utility Electric Rate:	**$ .05 Kwh**
Potential LEED Points =	**2 to 4**

There are some items that must be considered in the above analysis:

- The payback period of 13 years is considering present day rates of electricity of .05 per kilowatt hour in the area the plant is located. An inflationary rate is considered in conservative economic conditions. This clearly illustrates how the payback is directly related to the cost of electricity. A simple analysis can be concluded of electricity at .10 cents per kilowatt hour, the payback improves to 6.5 years.

- Other important factors that could improve the financial picture are federal and state tax incentives, credits, sales tax, value-added tax exemptions, and energy production payments. Further reading on these topics can be found at www.dsireusa.org.

- There is a similar production facility that was available to review the consumption requirements. Although the 16 MW calculated power illustrates the new facility's capacity, it has an interesting comparison to the referenced Plant 5.6 MWH usage.

- The LEED (Leadership in Energy and Environmental Design) points will be established when the plant is running production, and actual loading is measured. This value would then be compared to the measured solar capacity to determine the percentage of renewable power.

The above analysis considers an on-grid system. To accompany the technical evaluation, options need to be reviewed and described to the customer. The need for one-line diagrams and control systems need to be presented to the customer for a comprehensive understanding of how the solar system is integrated with the utility power system.

An off-grid may present some more viable advantages for the customer. For example, the manufacturing facility may have internal vehicle traffic for material handling. A likely scenario is these vehicles operate on batteries and have several centralized charging stations. An off-grid solar system dedicated to the charging stations may provide adequate power for a 3 shift operation, although supporting calculations would need to be established. This is similar to a typical solar system charging batteries to be used by the facility during off peaks.

7. Conclusion

The solar feasibility requires a combination of technical analysis, sun exposure levels, financial return, basic system configuration, and tax incentive considerations.
Further financial analysis of the benefits of solar energy to the end user is vital to validate the advantages. While there is a strong desire to improve the environment by the reduction of coal generated electricity, there needs to be strong financial incentives.

Anticipation of higher costs for coal provided electricity is difficult to predict, however with pressure to contain coal emissions, the associated costs will be passed on to the consumers. Thus investing in solar energy early, cost containment can be achieved prior to any possible escalation in traditional coal energies.

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About the Authors

Robert Meyers has spent 14 years conducting and supervising power distribution studies in industrial applications, primarily re-tooling production facilities where power balancing is required of removed and newly installed equipment. The total power of such facilities ranges from 20 MW to 30 MW. This work has been for a variety of clients while employed at Design Systems, Inc. in Farmington Hills, MI, USA.

The integration of solar power makes it ideally suited to distribute throughout the secondary power systems within an industrial manufacturing facility. Therefore, Mr. Meyers found it valuable to understand the methodologies to conduct Solar Power feasibility studies for industrial applications that included the economic and technological elements.

Dr. Alwerfalli is Professor of Mechanical Engineering and Director of Master of Engineering Management Program. He has over 36 years of industrial and academic experience. Prior to joining LTU in 1990, Dr. Alwerfalli assumed many engineering positions at various manufacturing industries. He is a very active consultant to the Automotive Industry. His technical expertise assisted many manufacturing companies develop effective Quality Management Systems, reduce waste and enhance quality and productivity. For the past 14 years he has been serving as a senior consultant at Advance Manufacturing Engineering of Chrysler. He developed and taught several training courses, seminars and workshops in Quality Systems, Environmental Management Systems, Lean Manufacturing, Six Sigma, Product Innovation and Design, Leadership and Management and Continuous Improvement for Chrysler, General Motors, DMU, CAMI, QPI, QUAD Industries, MDPITC, WELDMATION and many others. He conducted several diversity training programs on how to do business in the Middle East to oil companies such as ExxonMobil, CONOO Philips, Marathon Oil Co. Dr. Alwerfalli has numerous publications in many fields of expertise. He is also listed in who is who in engineering, recipient of many awards of excellence in teaching.

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