Utility Power Factor

Impact of PV Grid integration

Effect on Power Factor by integrating Solar plant to your existing power and ways to prevent the penalties of the system.

Large-scale utility must maintain their grid power factor (PF) according to the standards of their local grid provider. If the PF is not within permissible limits, the grid provider files penalties, in order to maintain power qualities. Generally domestic consumers pay only for their real power(kW) consumption- kWh. But, large-scale consumers' s electrical charges include real power(kW) consumption-kWh and reactive power(kVAR) consumption-kVARh. If we integrate the PV into grid without considering power factor, it creates unnecessary trouble.

Real Power (P), Reactive Power (Q), Apparent Power (S), Power Factor (PF):

In any electrical systems the load components comprise of resistive, inductive and capacitive loads. The real power is the function of the resistive component R of any system. In the resistive load, voltage and current are in phase, hence there will be no phase shift. The reactive power is the function of the reactive component X. In inductive & capacitive loads there will be phase shift between the voltage and current. The apparent power is the function load impedance Z.

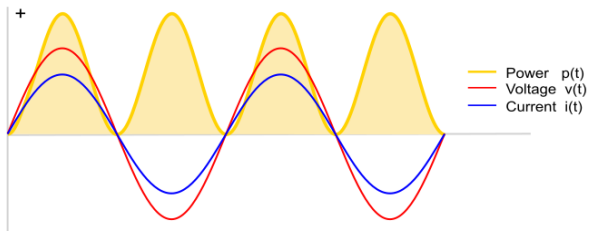

Fig 1: V, I & Power in a Resistive load

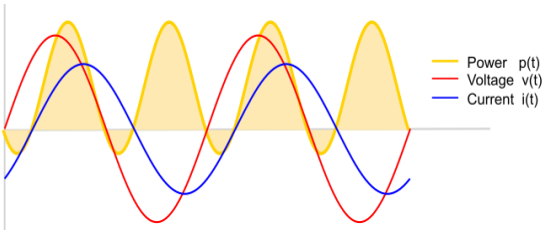

Fig 2: V, I & Power in a Reactive load

Power equation related to Power and Load components,

$$\textbf{Real Power (P)} = \mathbf{I^2R}\,;\ \textbf{Reactive Power (Q)} = \mathbf{I^2X}\,;\ \textbf{Apparent Power (S)} = \mathbf{I^2Z}$$

$$\textbf{Impendance Z} = \sqrt{(\mathbf{R^2 + X^2})}$$

The apparent power is a combination of real and reactive components. Fig-3 is a Power triangle, it explains Active/ Real, Reactive and Apparent Power relationship.

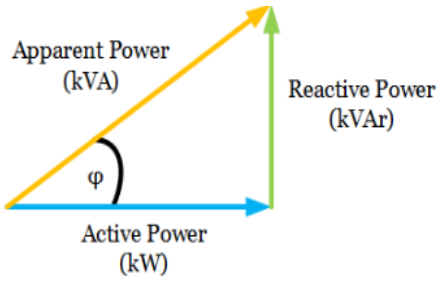

Fig 3: Relationship of Real, Reactive and Apparent Power

The cosine of angle between apparent power and real power is the power factor cos φ.

$$Power\ Factor\ (\cos\varphi) = \frac{Real\ Power(kW)}{Apparent\ Power(kVA)}\ ;\ PF(\cos\varphi) = \frac{P}{S}\ ;\ S = \sqrt{(P^2 + Q^2)}\ ;$$

$$Q = \sqrt{(S^2 - P^2)}$$

Impact of PV Grid Integration:

Mostly Solar inverter functions at unity power factor. The required active power to meet out the site demand will be taken from installed PV system and grid. However, required reactive power will be consumed from the grids. This leads to power factor issue.

For example, the site load is 100kW and power factor should be maintained at 0.91. Fig -4 explained actual condition.

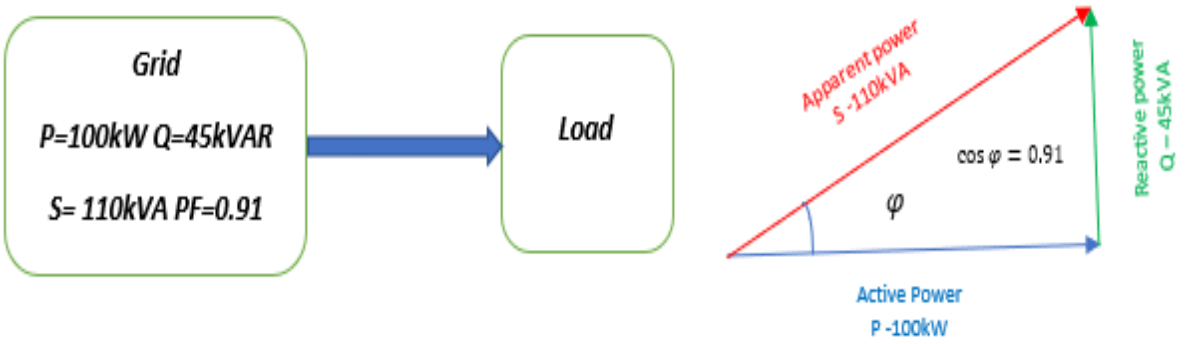

Fig 4: Normal Power Consumption System

If the same site has a PV system, the PV system will provide 50kW to the site load and remaining would be taken from the grid. Fig-5 explains the integrated PV- Grid working condition.

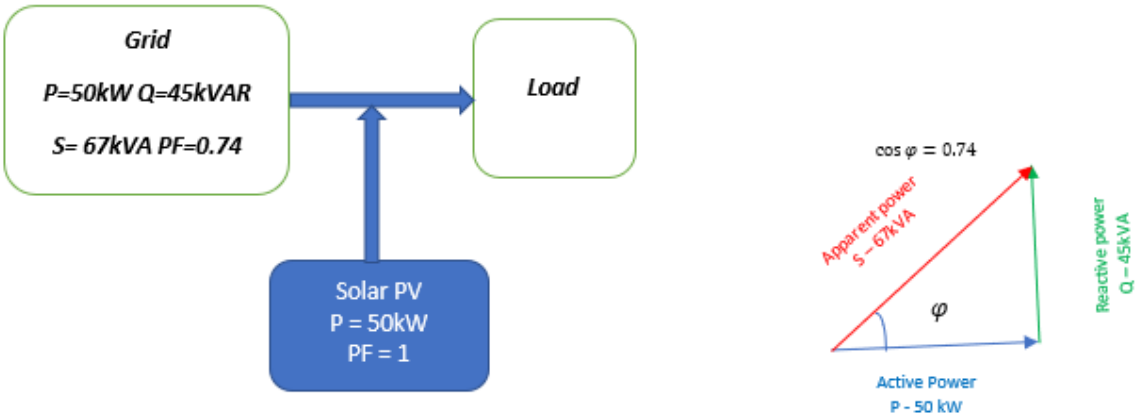

Fig 5: PV-Grid Integrated Power Consumption system

How to prevent the power factor penalty in the PV – Grid integrated Power Systems?

Method 1: To Set the Inverter reactive power / Power Factor

Most of the inverter is equipped with a feature to control reactive power and by setting the reactive power value/ power factor, we will compensate the reactive power and ensure the site power factor is maintained at a desired value.

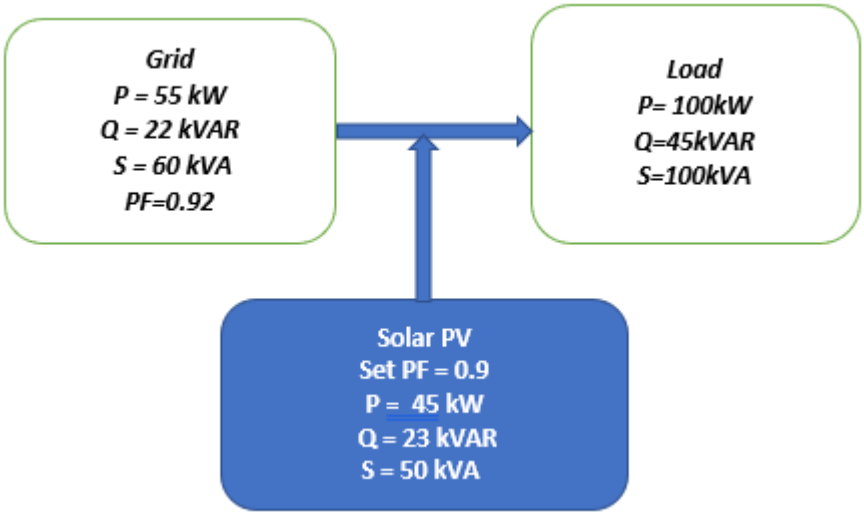

Fig 6: Power Consumption system after Inverter Reactive power setting

Method 2: To install reactive power Generator

Install an additional compensator / reactive power generator device to maintain the power factor. This reactive power compensator device frequently measures the power factor at site and automatically alters its reactive power value to ensure the PF is maintained at the desired value.

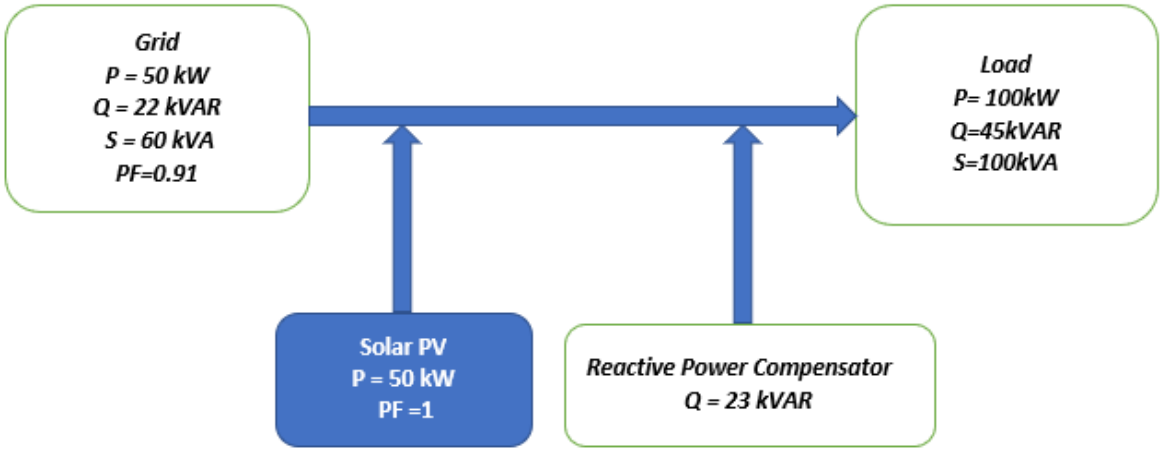

Fig 7: System Power Consumption system with Compensator

Method 3: Dynamic power control

In this method, an energy meter continuously measures the site P & Q Value and the power output of the inverter. A Controller device is introduced to read both measurement and regulate the inverter P & Q values as per the inverter limits and ensure the site power factor is maintained at desired value.

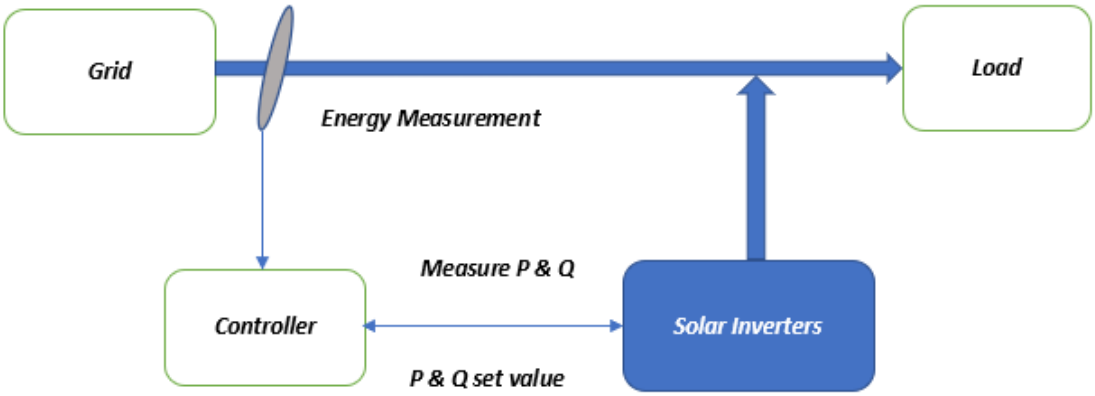

Fig 8: Dynamic Inverter Power Control

References

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2. Vrinda AV, Sheeja V, "Grid Connected Solar PV system with Power Quality Improvement", IJIREEICE,Vol-5,Issue-1,March2017.

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