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# Utilizing PV Solar Farms in the Night for Added System Benefits and Revenues

*by*

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## *Novel Concept*

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# Utilization of PV Solar Farm in the Night !



# Significance

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- New concept of utilizing solar farm as a Static Compensator **STATCOM** - FACTS Device
- “Utilization of Distributed Generator Inverters as STATCOM for Different Objectives”
  - PCT patent application filed for worldwide coverage; two US provisional patent applications filed
- Opens new opportunities for solar farms for earning revenues in the NIGHT



# PV Solar Farm

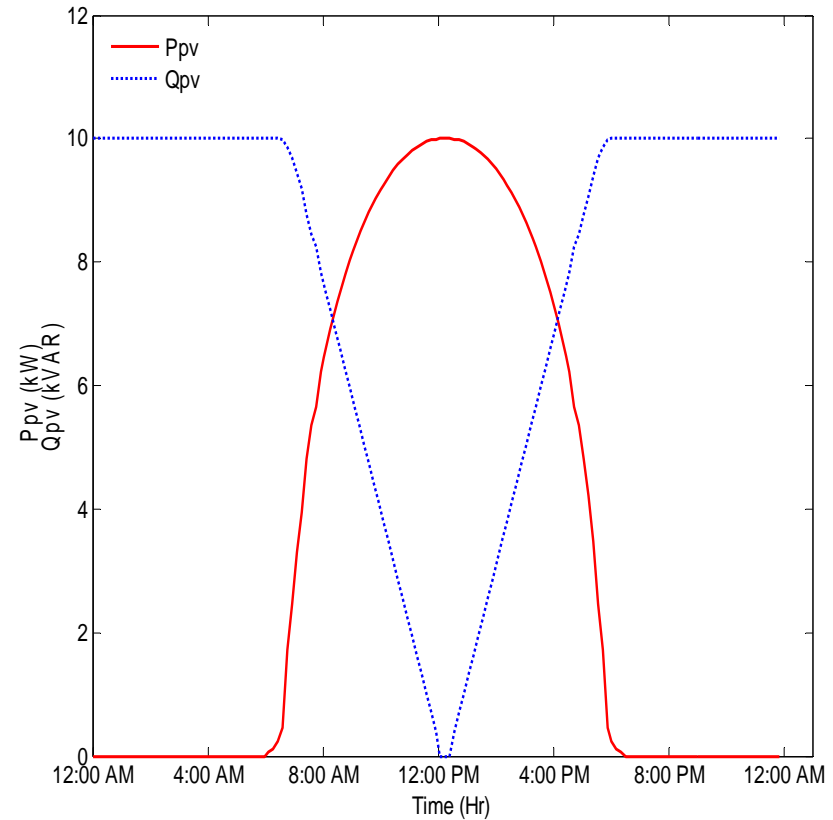
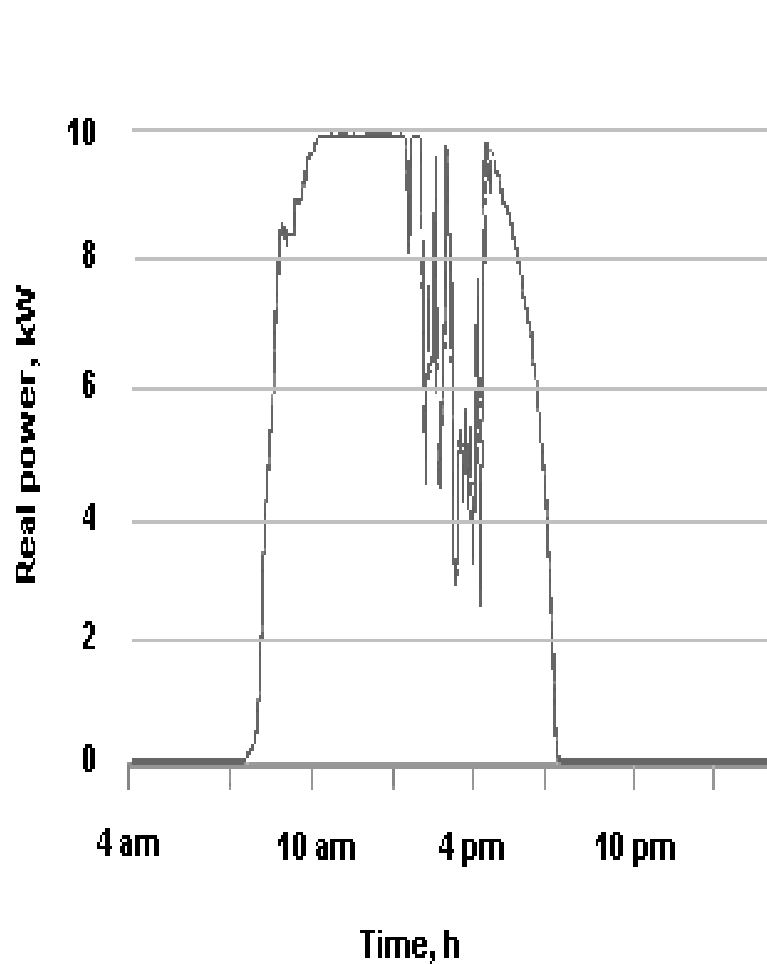
## Conventional Operation

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- Nighttime - idle
  - Inverter capacity totally unutilized in the night
- Daytime – real power generation
  - Inverter fully used only around noon time
  - Inverter partially used during rest of the day



# Typical PV solar system operation





# PV Solar Farm

## Proposed Operation

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- **Nighttime - as STATCOM**
  - Inverter capacity fully utilized for controlled reactive power exchange
- **Daytime – real power generation + STATCOM**
  - Remaining Inverter capacity utilized for controlled reactive power exchange



# Benefits of New Control

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- Increase connectivity of neighbouring wind plants
- Improve power transmission capacity
- Provide voltage regulation and power factor correction in distribution utilities

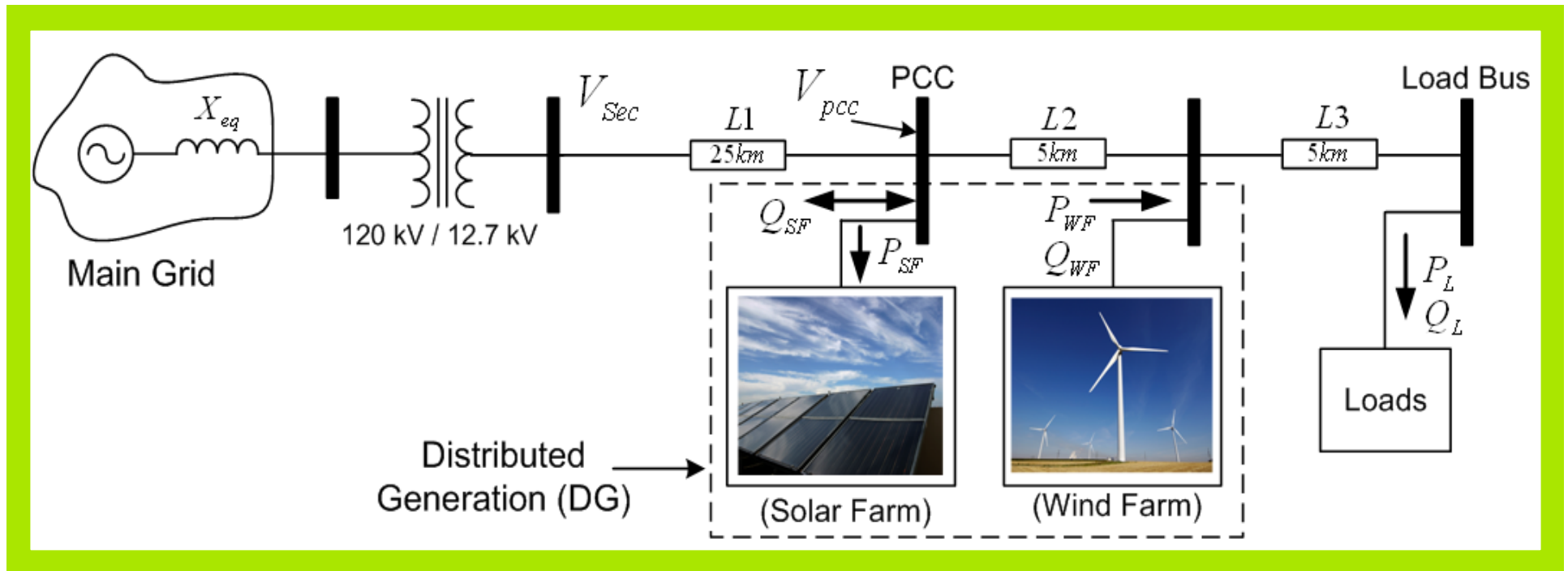


# Increasing connectivity of neighbouring wind plants

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- **OPTIONS** for increasing wind connectivity:
  - Install expensive voltage regulation equipment e.g. SVC or STATCOM
  - Utilize the proposed new control on a neighboring PV solar farm as STATCOM
- **This new control allows an idle PV solar farm to**
  - help a wind farm when it needs voltage regulation the most – in the nights.

# Realistic Study System



- 4.5 MW PV solar farm
- 15 MW wind farm



# Increasing connectivity of neighbouring wind plants (cont'd)

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- A 4.5 MW solar farm as STATCOM helps to connect an additional 7 MW of wind power in the night bringing ~ \$2.1 Million new revenues for wind farm
- Similar nighttime benefits also achievable to substantial degree during daytime
- Cost of new Solar Farm Controller **several orders of magnitude lower** than a conventional STATCOM



# Significance

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- Potential to bring
  - Increased profits to wind farms
  - New revenues to solar farm during nights
  - Better network performance for network utilities e.g. Hydro One



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# Novel control of PV Solar Farm for increasing Stable Power Transmission capacity



# Transmission Challenges

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- Everyone wants to add more wind and solar systems
- Do the transmission lines have capacity to transfer this additional power?
  - Perhaps No!
- Major challenge being faced by power industry



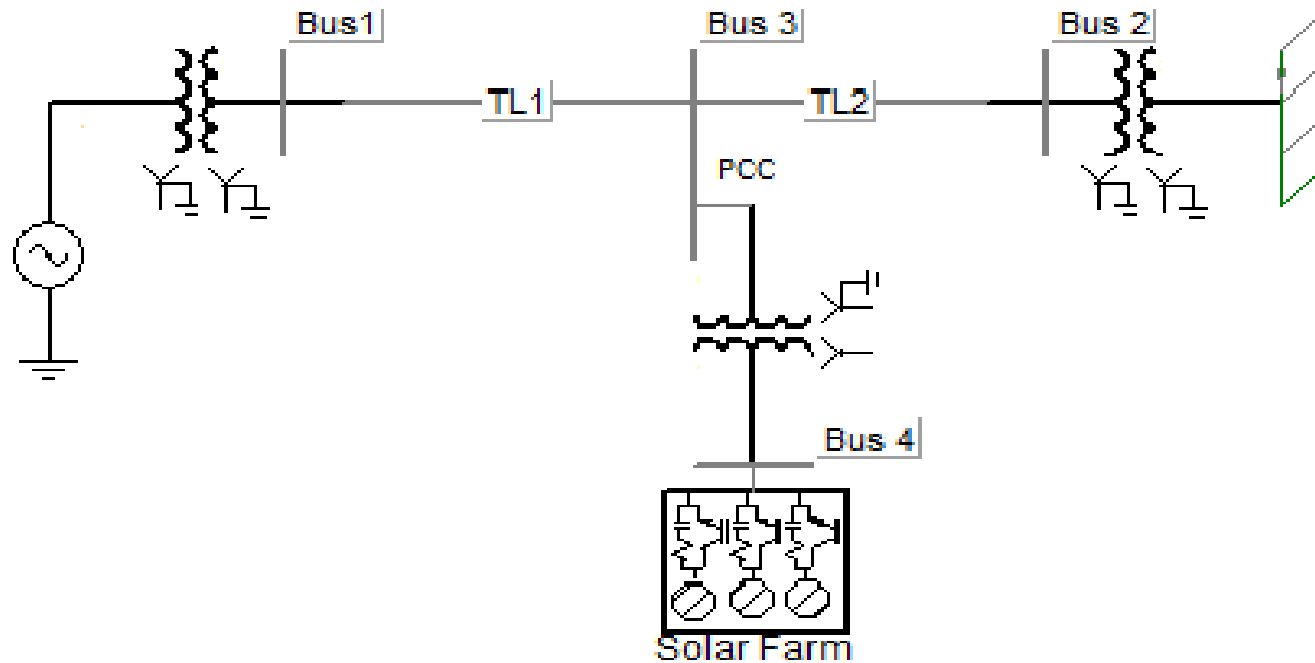
# Transmission Challenges

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## Options to deal with this challenge:

- **Construct new transmission lines: \$ 0.5 Billion**
- **Add FACTS Devices: \$ 50-60 Million**
- **Innovative Controls on Solar Farms:  
~\$ 500,000**

# Realistic Study System



Large generating complex supplying power over a 200 km line at 400 kV.

A 100 MW PV solar farm is connected at line midpoint.



# Increasing transmission capacity

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- A **100 MW solar farm** with the novel controls can increase transmission limit by
  - **200 MW in the night** when there is no power generation, and
  - **97 MW during the day time** while the active power generation level is high (**about 94MW**)
- Cost of new Solar Farm Controller **several orders of magnitude lower** than a conventional STATCOM



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# **Novel control of PV Solar Systems for voltage regulation and power factor correction in a distribution utility**



# COMMERCIALIZATION

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London Hydro  
will be showcasing this new PV technology on  
**two 10kW PV solar systems**  
to be installed in London, Ontario, Canada  
In Fall 2011

- *First in Canada*



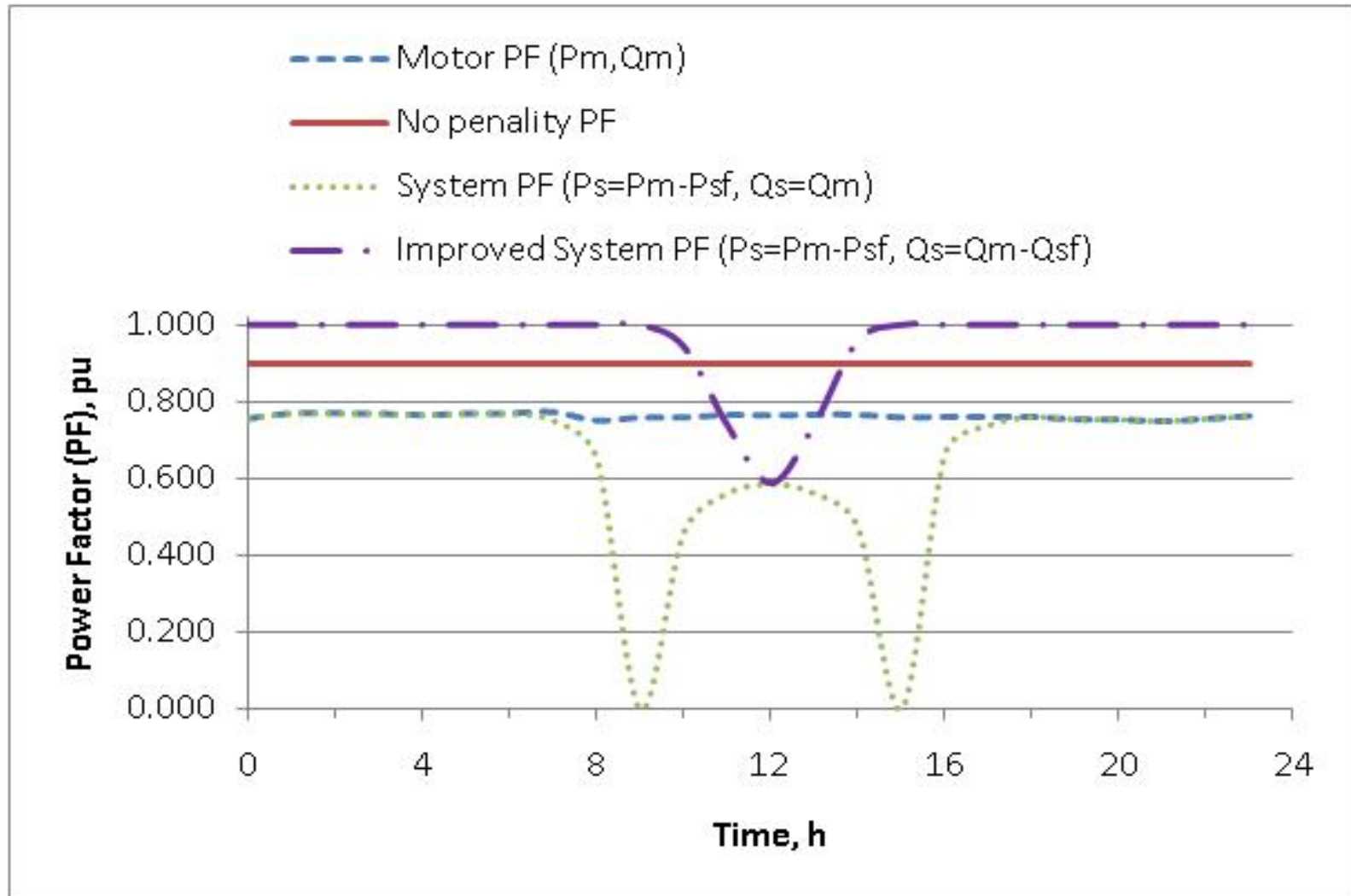
## SYSTEM DESCRIPTION

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- The 10 kW PV solar system is connected at the terminals of the 6 kW induction motor
- The motor constantly operates a power factor 0.76
- Objective of PV solar farm control is
  - Power factor correction
  - Voltage regulation

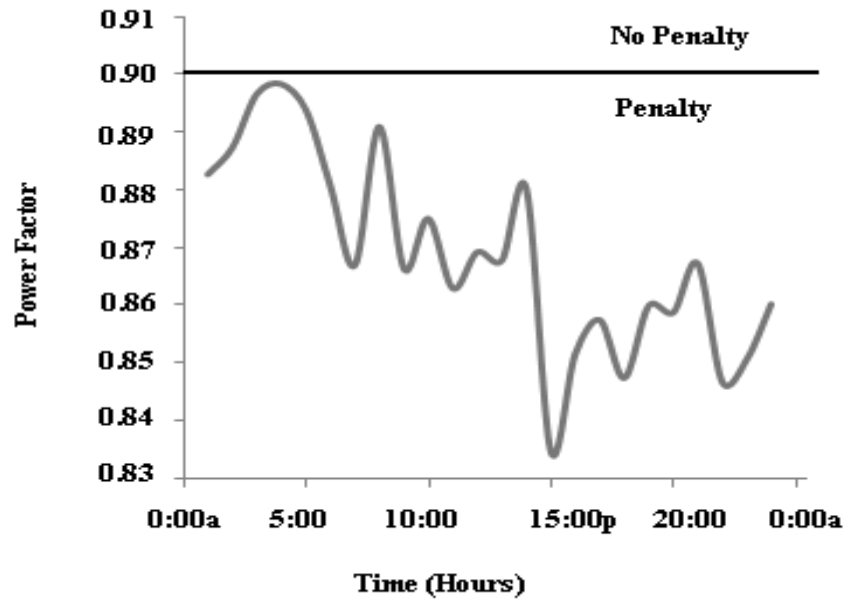


# Solar Farm as STATCOM – Power Factor Correction: Steady State

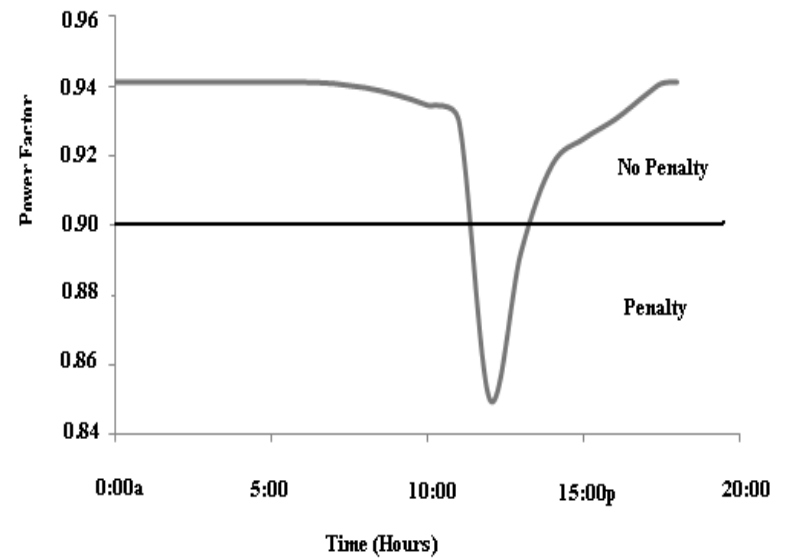




# Power Factor Correction



Power Factor Variation of an industrial load with 100% loading of 45kVA transformer

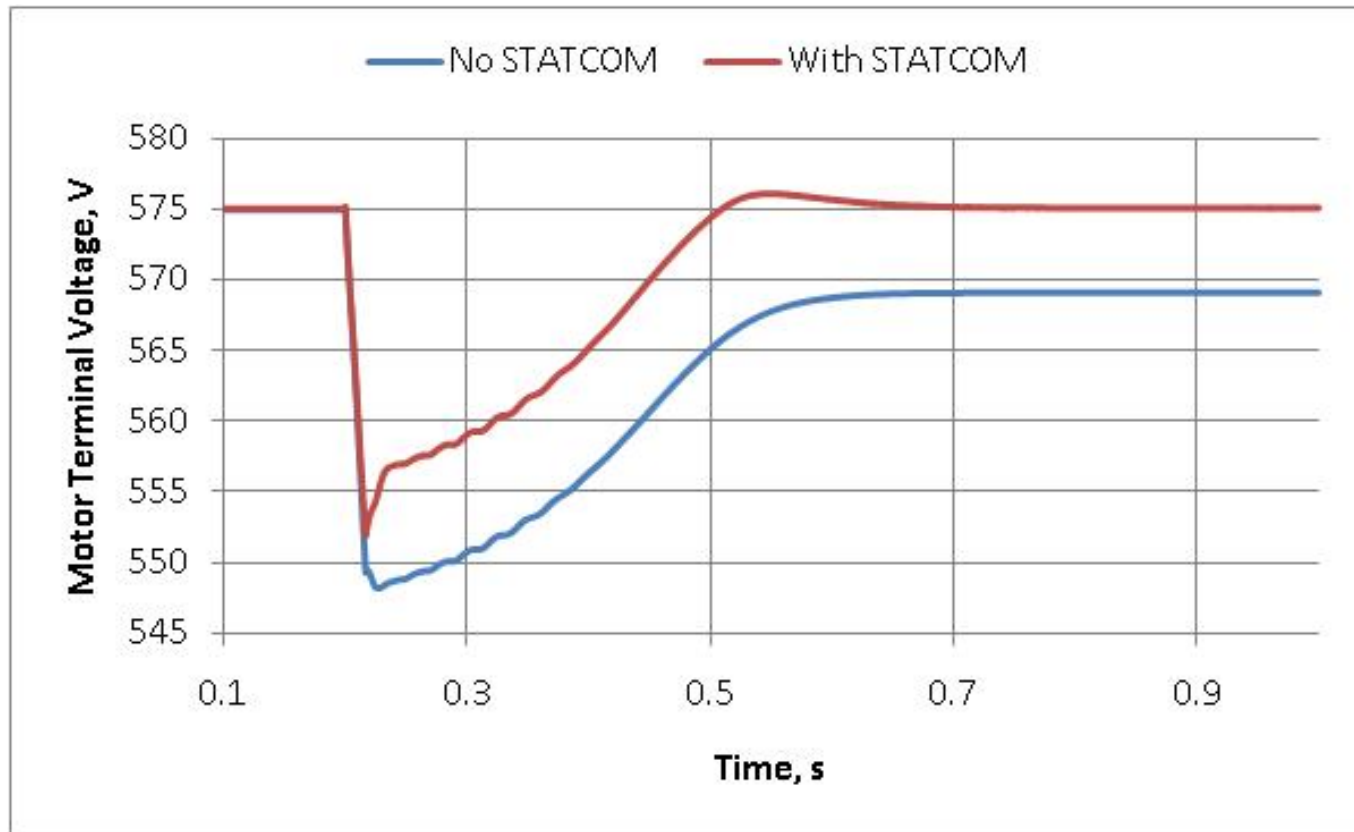


Power Factor Variation with the novel PV controller with 100% loading of 45kVA transformer

Penal tariff avoided both in night and day by the novel PV solar system control



# Solar Farm as STATCOM – Nighttime Voltage Control: Transient State



- $P_{\text{solar}} = 0 \text{ kW}$ ,
- Available  $Q_{\text{solar}} = 10 \text{ kVAr}$



# Significance

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- Potential for
  - Avoiding penal tariffs for motor loads operating at low power factor
  - Improved voltage regulation – thereby reducing the need for additional voltage controlling equipment
  - Better network performance, for distribution utilities e.g. London Hydro
  - New revenues to solar farm during nights



# IMPLEMENTATION SCHEDULE

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- The new control systems will be designed for the PV solar plant and its potential benefits will be investigated through:
  - Software EMTDC/PSCAD studies (Done)
  - Real Time Digital Simulator (In Progress)
  - 15 kW UWO-London Hydro Lab with TerraSAS Solar Simulator (July 2011)
- Finally installed in the London Hydro in Fall 2011



## *Proposed Novel Concept*

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**Equally Applicable for  
Inverter Based Wind Farms during  
No-Wind or Partial-Wind  
Conditions !**



# Major Funded Projects

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- OCE – Centre of Energy, “*Large-Scale Photovoltaic Solar Power Integration in Transmission and Distribution Networks*”, awarded \$ 6 Million to Rajiv Varma Western Lead PI;
  - co-funded by Ontario Power Authority (OPA), Hydro One Networks Inc, First Solar Canada, London Hydro Inc, and Bluewater Power
- OCE – Centre of Energy, “*Increasing Renewable Generation Connectivity in the Transmission System of Ontario through use of Innovative DG Controls*”, awarded \$ 960,000 to Rajiv Varma as PI;
  - co-funded by IESO, Hydro One Networks Inc, London Hydro Inc, Bluewater Power, Testforce equipment



# Next steps

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- Western looking for partnerships with **utilities**, solar/wind farm **developers** and **inverter manufacturers** in Canada and abroad  
for  
**commercialization of proposed novel nighttime controls** on PV solar farms and wind farms



# CONCLUSIONS

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- Novel Control of PV solar farm as STATCOM proposed – *First showcase in Canada*
- Increasing utility of solar farm by providing various benefits at **several orders of magnitude lower cost** than conventional technologies
- Potential to bring
  - New revenues to solar farm during nights and day
  - Better network performance for utilities



# References

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- [1] Rajiv K. Varma, V. Khadkikar and R. Seethapathy, “Nighttime Application of PV Solar Farm as STATCOM to Regulate Grid Voltage”, *in IEEE Transactions on Energy Conversion (Letters)*, vol.24, no.4, pp. 983-985, December 2009.
- [2] R.K. Varma, S A Rahman, and R. Seethapathy, “Novel Control of Grid Connected Photovoltaic (PV) Solar Farm for Improving Transient Stability and Transmission Limits Both During Night and Day”, *Proc. of World Energy Conference*, Montreal, September 2010
- [3] Rajiv. K. Varma, Shriram. S. Rangarajan, Iurie Axente and Vinay Sharma, “Novel application of a PV Solar Plant as STATCOM during Night and Day in a Distribution Utility Network”, Presented in the *FACTS Panel Session in the IEEE PES Power System Conference and Exposition*, Phoenix, AZ, USA, March 20-23, 2011



*Thank You*



## Can Solar Farms be Connected as STATCOM?

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### In the Night:

- Yes!
- Solar farms with solar panels disconnected and novel inverter control incorporated, completely become STATCOMs – i.e . Regulators. They no longer remain solar farms.
- Permission should then be sought to connect STATCOMs (not solar farms) to the networks of Transmission/ Distribution Utilities
- IEEE 1547 (and its restrictions) may not apply in this case, because this standard applies to DGs, and not to STATCOMs. Utilities and system regulators will welcome connections of STATCOM - voltage regulators.
- Solar developers can then accomplish all the benefits of the new technology.



## Can Solar Farms be Connected as STATCOM?

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### In the Day:

- Yes!
- The revised version of IEEE 1547.8 is being developed, which is expected to give permission to Distributed Generators such as solar farms to perform voltage regulation and other functions.
- The proposed new technology can then be implemented with mutual agreement between the solar farm developer, utilities and system regulator.