SCADA System for Remote Control and Monitoring of Grid Connected Inverters

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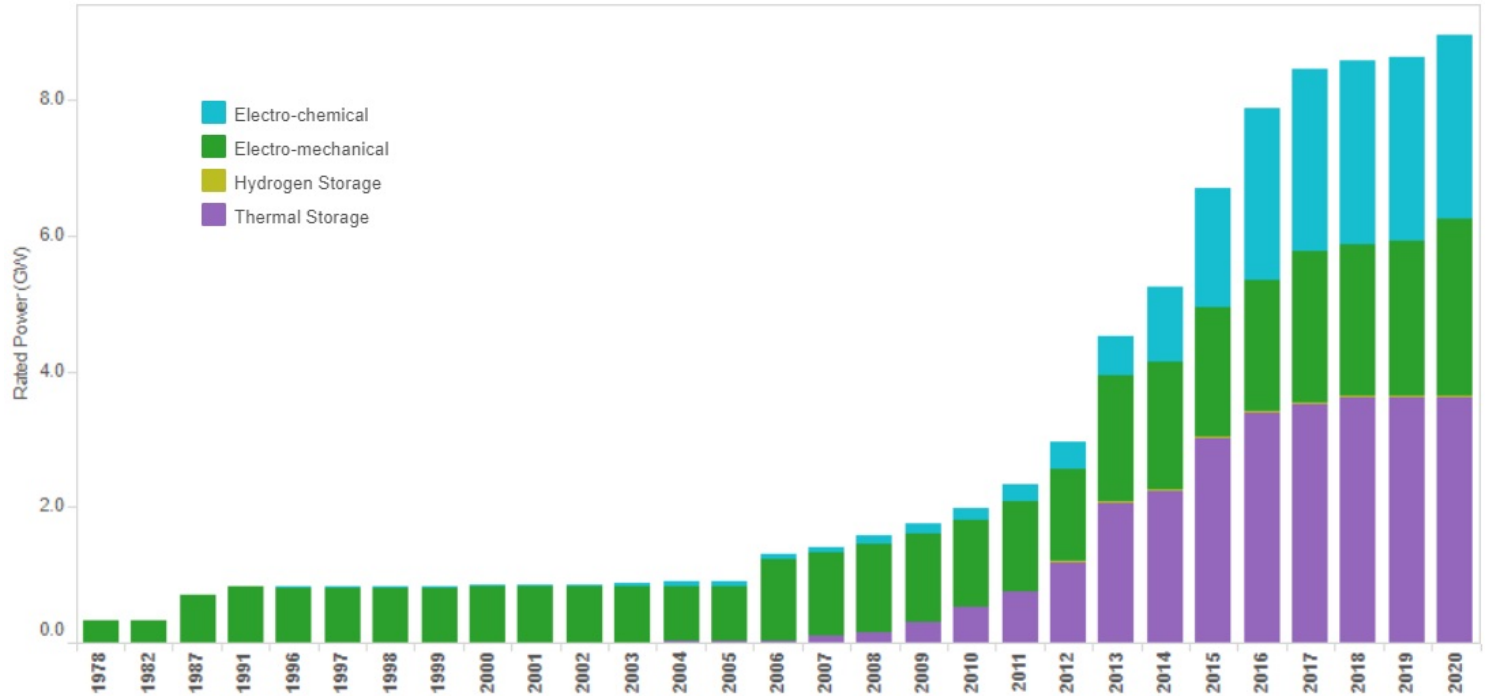
Outline

Motivation

According to the DOE global energy storage database, electro-chemical energy storage systems are increasing. [1]



[1] https://www.energystorageexchange.org

Motivation

- With number of energy storage systems, number of inverters connected to the grid is also increasing.
- Inverters are needed to be monitored and controlled by the utility,
  - to maintain the quality of the power supplied.
  - to stabilize the grid.
  - to maintain the energy price.
- Therefore, Supervisory Control And Data Acquisition (SCADA) systems are needed for grid-connected inverters.

Introduction

- S. G. Hegde [1] introduces a low-cost SCADA which behaves as a Remote Terminal Unit (RTU) and helps in gathering the data from the PLC.
- Design of a remote control plug using ESP8266 module is presented by Y. P. Zhang et .al. [2]
- A. M. Gurilo et al. [3] present a web-based SCADA software called Mango.

Research Objectives

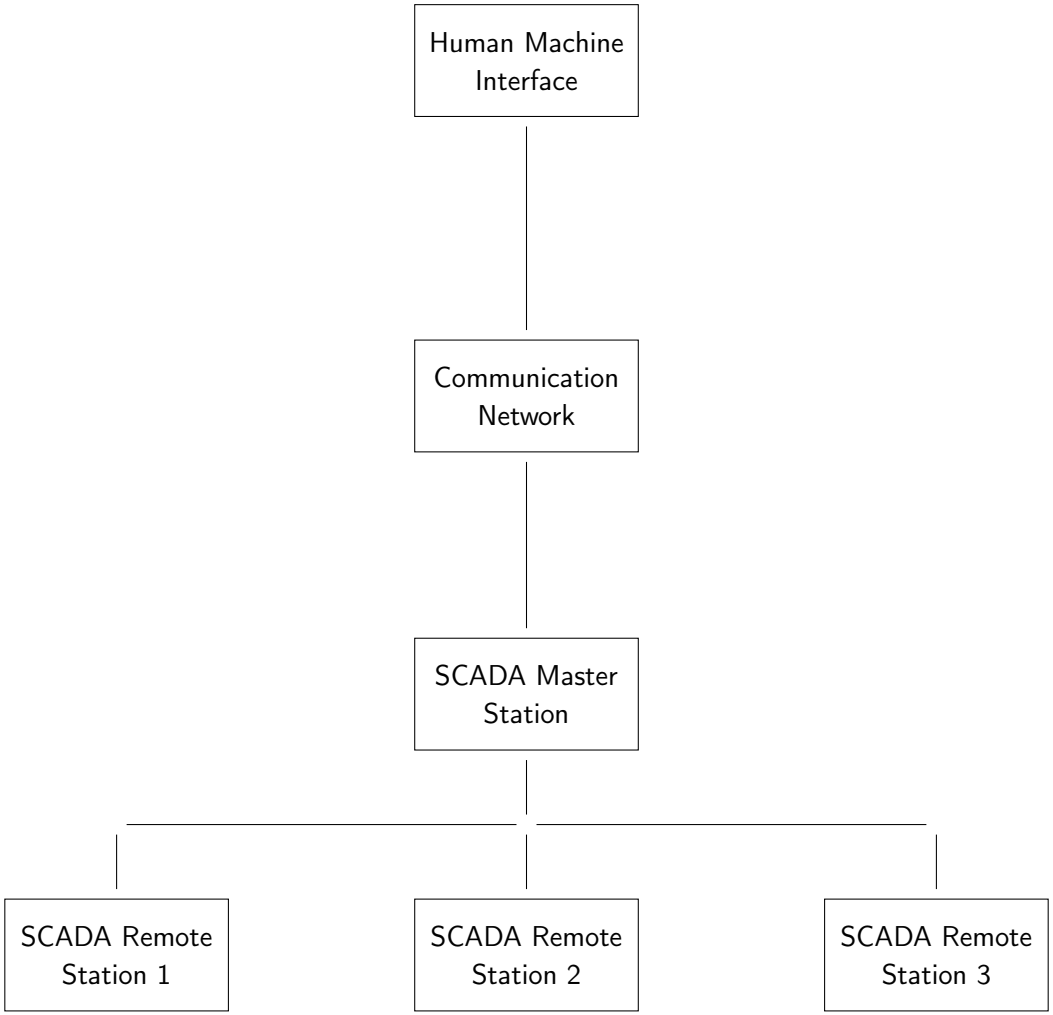
Goal

Develop a low-cost SCADA for monitoring and control of a grid tie inverter.

Objectives

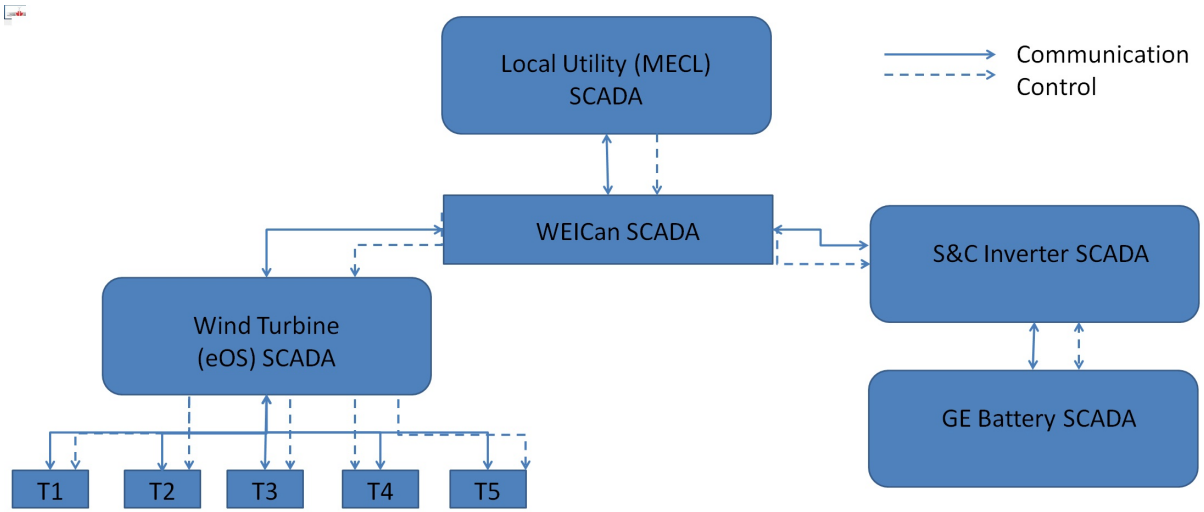
1. Identify main features of SCADA systems.
2. Compare available low-cost SCADA options
3. Develop a low-cost SCADA with features identified under the objective one.
4. Develop controlling strategy for an inverter connected an energy storage system to maximize the profit.

Typical Arrangement of a SCADA



SCADA systems used at WEICAN

- Defined features of a SCADA system used for monitoring and control of inverters connected to energy storage.



Features Identified

- SCADA should be capable of communicating with the inverter and the upper-level SCADA systems.
- Monitoring
  - Allows monitoring system in real time
  - Allows the user to view historic data for different intervals
  - Allows generating reports based on past data
  - Alarms the user in predefined events
- Control
  - Let the user control the device through a GUI
  - Automatic controlling is given at possible scenarios

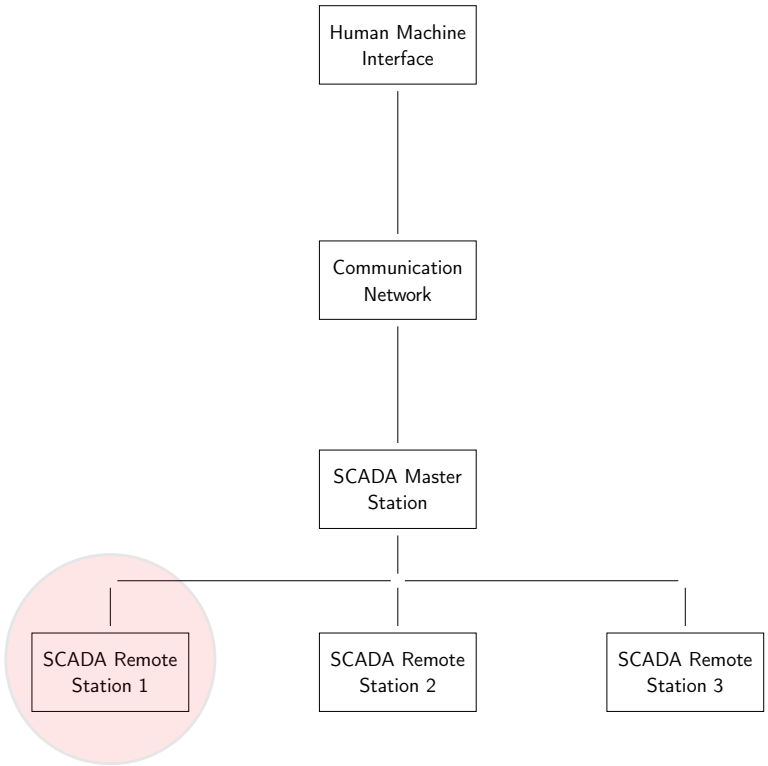
Features Identified

- Security
  - Adding different authorization levels
  - Using a firewall
  - Using locally installed servers for all operations
- Redundancy
  - Adding redundant data storages
  - Adding data storage near to the remote SCADA stations.

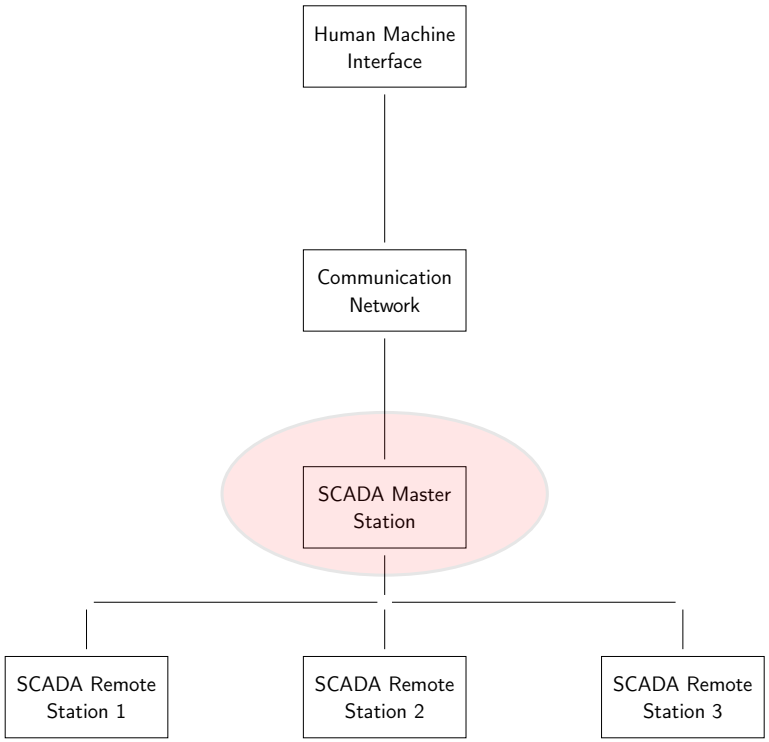
IoT Hardware-Based Low Resource and Limited Storage SCADA Systems

- Commercial SCADA systems are expensive. For an example VTSCADA, [2]
  - Initial cost: 1,000 I/O tag Development Runtime package, CAD 5,595.00
  - Maintenance and emergency support 20% annual fee from the initial price.
- Some expensive inverters comes with embedded SCADA systems.
- Low-cost and same quality inverters does not comes with SCADA systems

[2] https://www.trihedral.com



Client Side

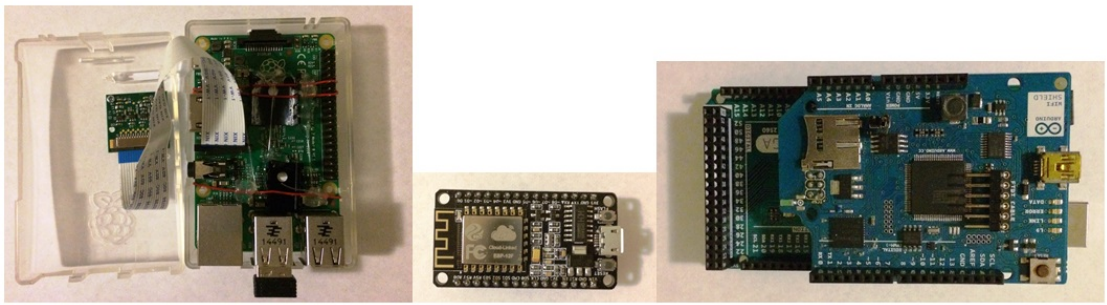


Server Side

Evaluation: Client side

Method	**Cost (CAD)**	**Drawbacks**
ESP12E	15.00	Weak wi-fi signal, 3.3V
Arduino with Wi-fi	150.00	Low Memory and slow, Larger in size and need more power
RPI	200.00	Reliability depends on the SD card reliability,3.3V pins, No analog I/O

Based on the cost perspective ESP12E is selected.



Evaluation: Server Side

Following systems were tested for the server side,

- Remote desktop connection with local data storage
- Open SCADA software (RAPIDSCADA)
- Cloud assisted IoT SCADA
  - UBIDOTS
  - Thingspeak
  - Blynk
- Local cloud assisted IoT SCADA systems

Based on the security, easiness of using and adding new components local cloud assisted IoT SCADA system recognized as the most suitable option.

Evaluation of cloud assisted IoT based SCADA

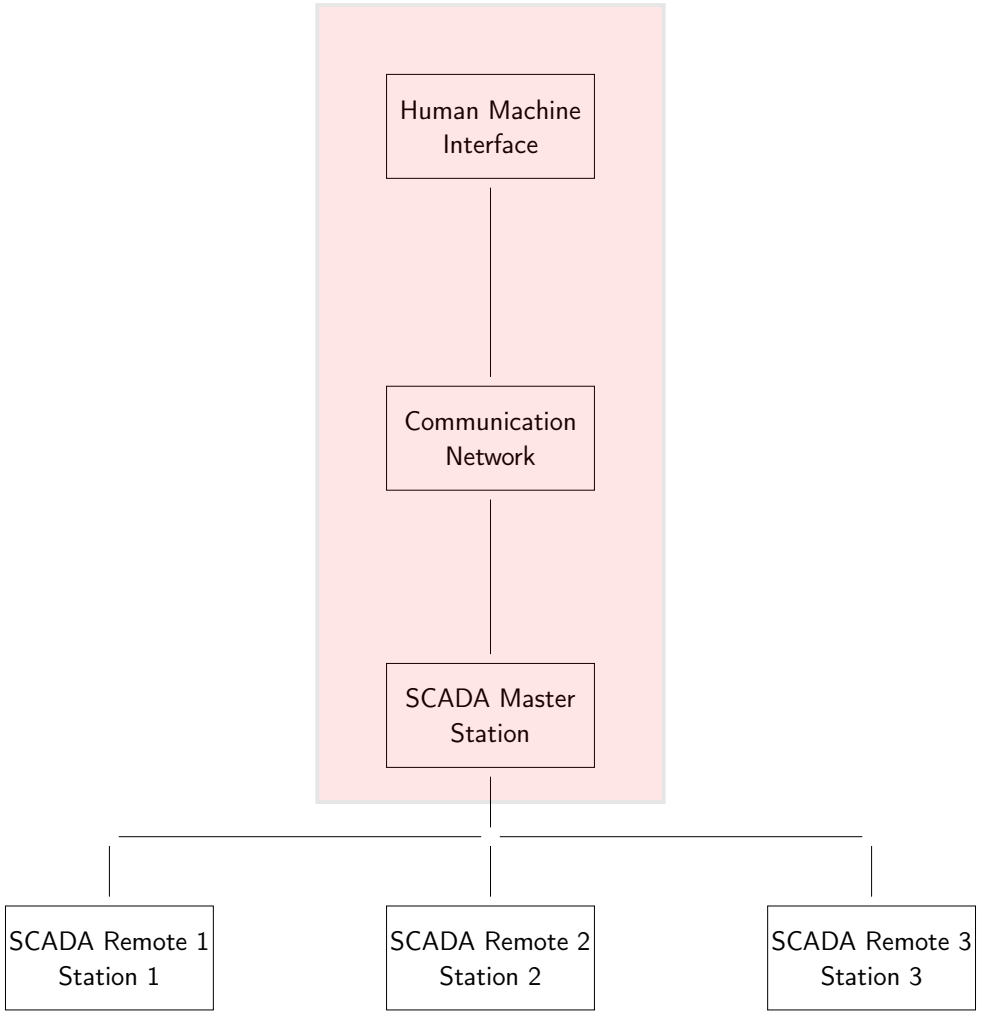
Method	**Installation**	**Ease of Using**
Blynk	Easy to install,need Windows computer	Easy to develop, but only through mobile app
Netlab Tool Kit	Easy to install, need Windows/ Linux computer (tested in Ubuntu 16.04)	Easy to use and configure but no GUI
Thingspeak	Difficult to install,need Linux computer	Easy to use in a web browser

Based on the easiness of using and features offered ''thingspeak'' based local cloud assisted IoT SCADA server identified as the most suitable option for the server side.

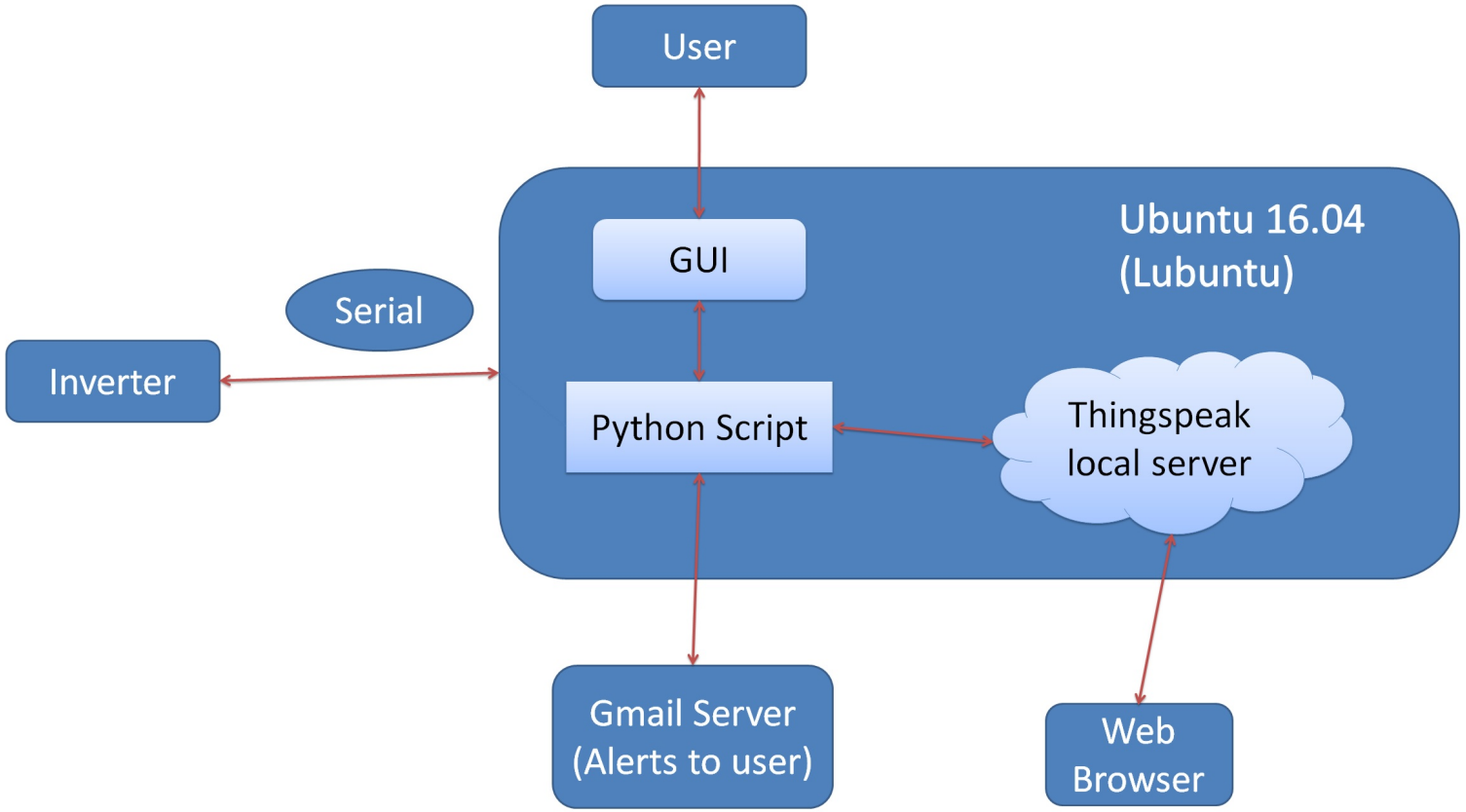
SCADA system Based on Private thingspeak Sever

- Locally installed ‘’thingspeak” server does not offer following features,
  - Interfacing equipment directly
  - Alarming system
  - A GUI to set control parameters
- Therefore SCADA has been developed with following functions,
  - Communication with the inverter
  - Data logging
  - Presenting data to the user
  - Send email alerts at critical conditions

Scope of the development

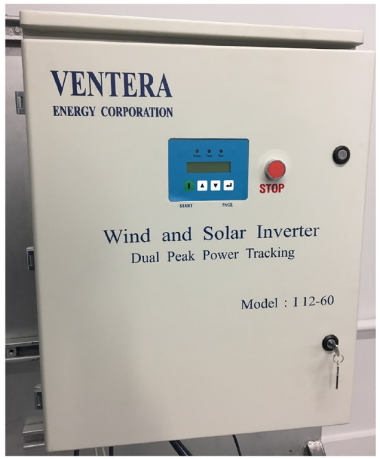


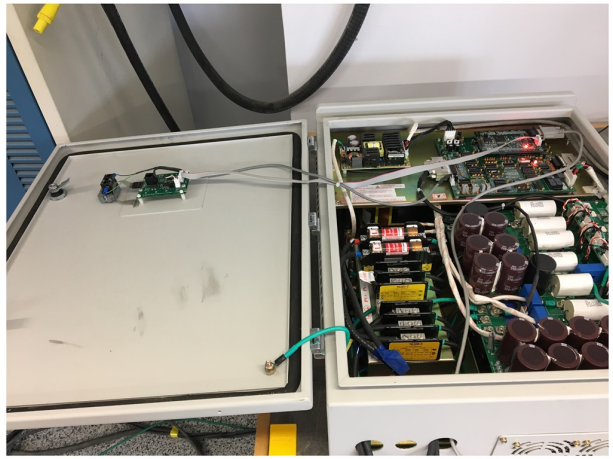
Block diagram for the Inverter SCADA



Evaluation of the developed system

- Tested with an actual inverter.





Evaluation: Commercial SCADA Vs. Developed SCADA

Feature	VTscada	Inverter SCADA
Cost	5000 CAD without hardware	0 CAD without hardware,200 CAD for hardware
Number of data points	1000 data points for the above cost	There is no limitation on number of data points
Reporting	Allows user to create many reports	Only few reports types of reports are available. But can be developed
Protocols	Modbus, DF1, CIP/ENIP, Siemens S7, Omron Host Link, OPC	Only one protocol but Can be developed for any protocol
Training	Special training is needed	No training required
Security	System is protected using passwords	Password protected and the controlling is not connected with the server.
Operating System	Windows	Linux (64 bit)
Maintenance cost/ license fee	20 % of initial cost(annually)	User maintained

Evaluation: Security

- To evaluate the security the developed SCADA is compared with a cloud-assisted IoT SCADA.
- Comparison shows that the developed SCADA reduces security issues associated with data logging and ownership.

Control Strategies for Remote Control of a Grid Tie Inverter and Its implementation using Low-Cost SCADA system

Addresses the optimum controlling problem of energy storage systems.

[1]https://www.cnet.com/news/hawaii-wind-farm-leans-on-giant-battery-bank/

Optimal charge/discharge scheduling of BESS

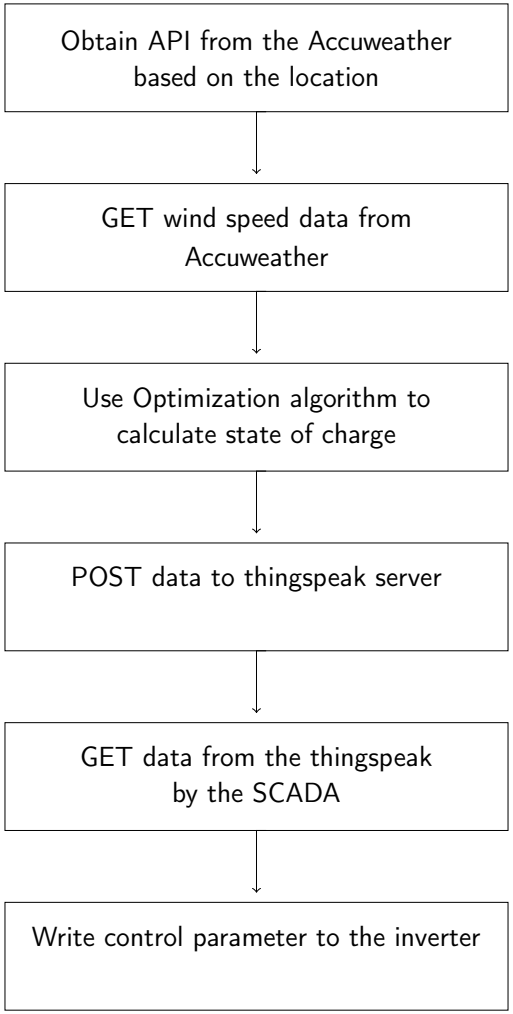
Conventional approaches

- D. K. Maly et al. [4]: Dynamic Programming algorithm (DP)
- S. H. Mohammad et al.[5]: Lagranges Relaxation (LR)
- H. L. Chin et al. [6]: Multi-Pass Dynamic Programming (MPDP)

AI based algorithms:

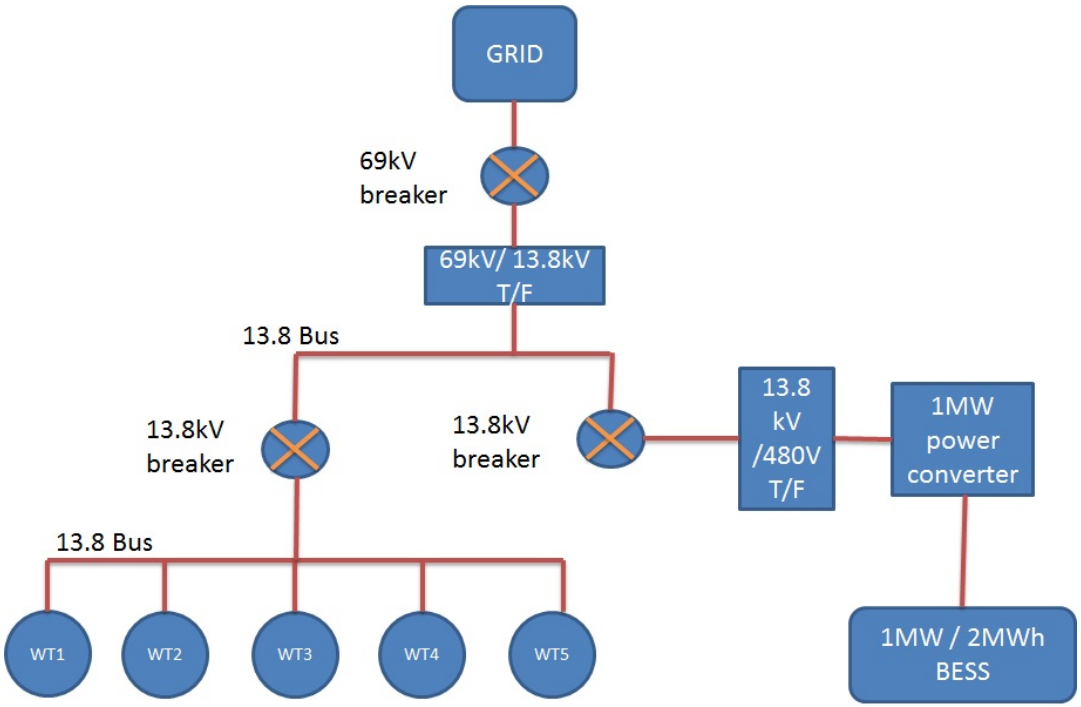
- D. H. C. Thai et al. [7] : Evolutionary Programming (EP)
- L. Tsung-Ying et al. [8]: Particle Swarm Optimization (PSO)
- C. C. F. Lance et al: [9]: Fuzzy and Genetic Algorithm combined approach

For this SCADA linear programing based algorithm is developed due to its simplicity.


Obtain API from the Accuweather based on the location
GET wind speed data from Accuweather
Use Optimization algorithm to calculate state of charge
POST data to thingspeak server
GET data from the thingspeak by the SCADA
Write control parameter to the inverter

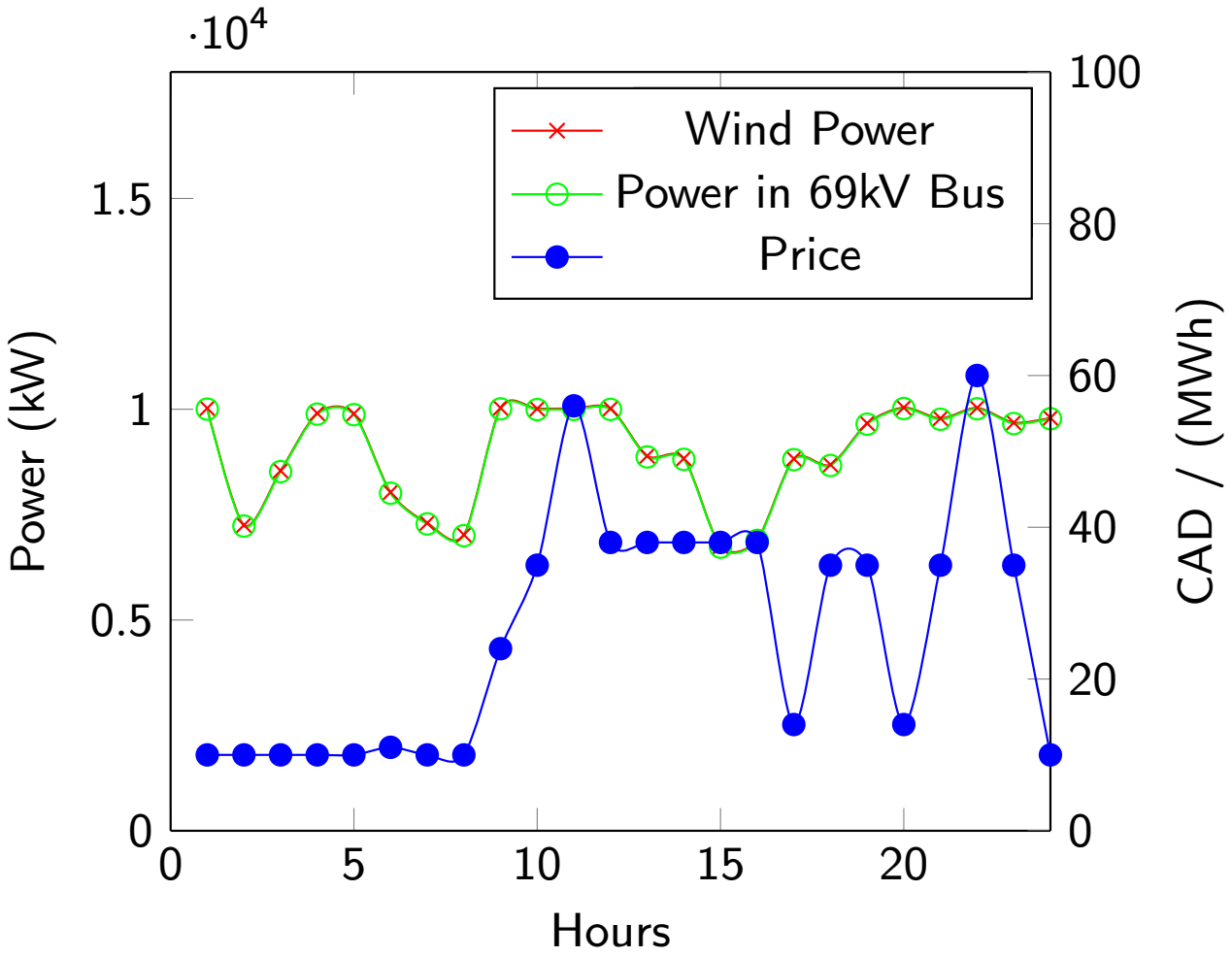
Evaluation: Validation of the algorithm

- Data obtained from the wind park in WElcan has been used for validation.
- Single line diagram for the wind park.

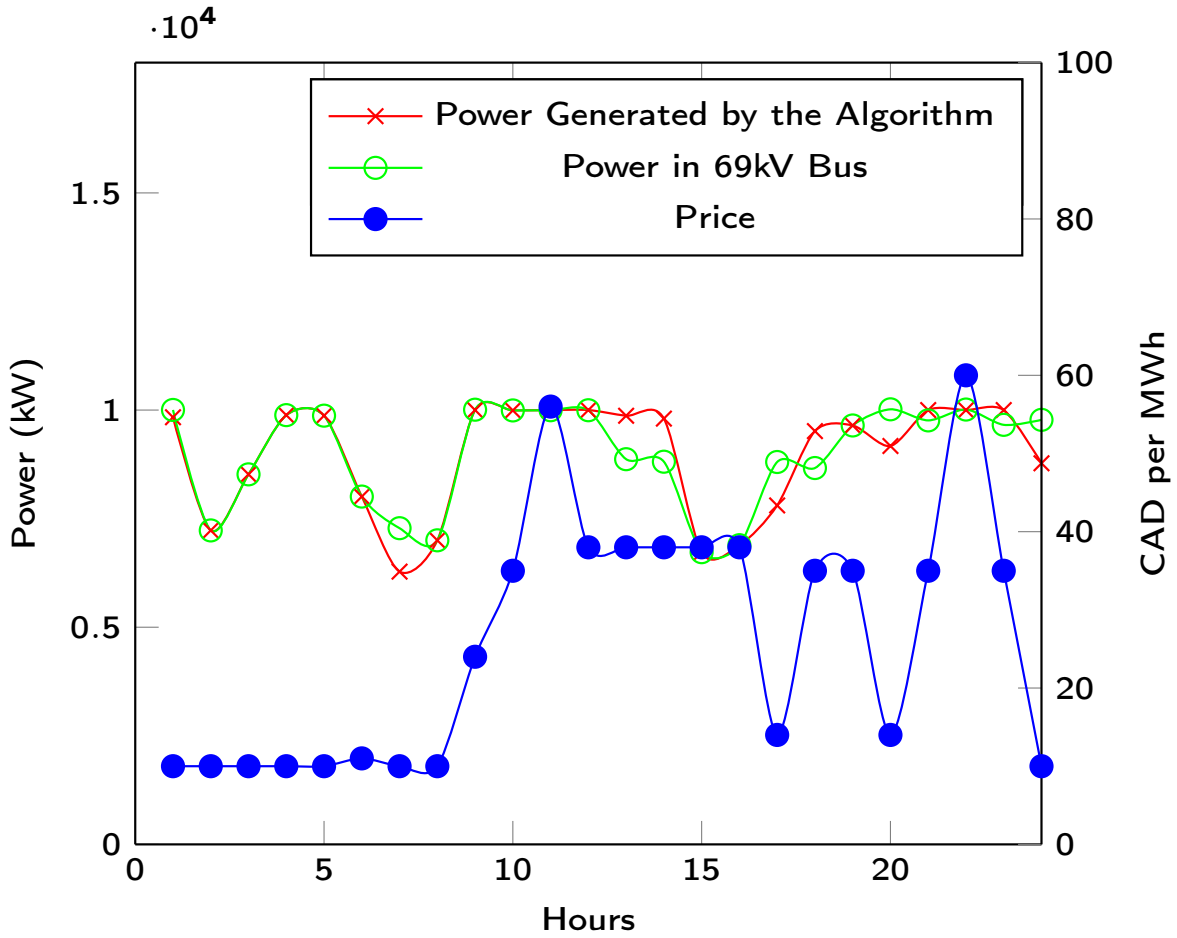


Five 2 MW DeWind turbines 13.8 kV

Evaluation: Data from WEICAN



Evaluation: Output from the algorithm



Summary

As a summary, this thesis has made following contributions to the field of SCADA systems,

- Recognized and documented core features that needs to be embedded in a SCADA which is used for monitoring and control of an inverter.
- Developed a low-cost open-source SCADA for monitoring and control of a grid-connected inverter.
- Developed an optimization algorithm to maximize the profit generated by an energy storage.

Future Work

- Reduce the phantom load: Since the implemented SCADA server consumes around 52VA which is high and not suitable for small-scale energy storages. Therefore, the server needs to be installed in a low power consumption computer and test it.
- Number of protocols: The developed system communicates only with the given protocol. Therefore, the system needs to be improved with more protocols.
- Optimum usage of home energy storage: Minimize the electricity bill for households by training a neural network to predict the load pattern for the house and optimally control the BESS.

Publications

Journal Articles

- Sarinda Jayasinghe, Tariq Iqbal and George K Mann, An Internet of Things based open SCADA for Monitoring and Controlling of Inverters, submitted with IEEE Access 2017

Peer-reviewed Conference Articles

- Jayasinghe L. Sarinda, Tariq Iqbal, George Mann, Low-cost and open source SCADA options for remote control and monitoring of inverters, presented at CCECE 2017, Windsor ON Canada.

Abstract-reviewed Conference Articles

- Sarinda Jayasinghe, Tariq Iqbal, George Mann, Optimum Control of a Grid Connected Battery Energy Storage, accepted to present at 26th IEEE NECEC conference 2017.
- Sarinda Jayasinghe, Tariq Iqbal, George Mann, IoT based low-cost SCADA system for an inverter, presented at 25th IEEE NECEC conference 2016.

Poster presentations

- S.L. Jayasinghe, T. Iqbal and G. Mann, Internet of Things (IoT) based open SCADA for Monitoring and Controlling of Inverters, Poster session presented at NESTNet Technical Conference. 1st Annual conference. 21-22 July 2017; Toronto, ON.

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Thank You !


S. G. Hegde, S. R. Desai, D. R. Gajanan, S. B. Kowligi and Sachin RC. ndustrial Instrumentation and Control (ICIC). "Implementation of SCADA in industries using wireless technologies." 2015. Pune.


P. Zhang, T. Liu, Z. X. Yang, Y. Mou, Y. H. Wei and D. Chen,. 2015. "Design of remote control plug." 2015 IEEE International Conference on Applied Superconductivity and Electromagnetic Devices (ASEMD). 29-30.


A. M. Grilo, J. Chen, M. Díaz, D. Garrido and A. Casaca,. 2014. "An Integrated WSAN and SCADA System for Monitoring a Critical Infrastructure." (IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS) 10 (3).


D.K. Maly, K.S. Kwan. 1995. "Optimal battery energy storage system (BESS) charge scheduling with dynamic programming." IEE Proceedings - Science, Measurement and Technology.


M. S. Habibi. 2001. "Model for impact of storage on spinning reserve requirements and distributed generation." Proceedings of the 33rd Southeastern Symposium on System Theory 161-165.


Chin H. Lo, Max D. Anderson. 1999. "Economic dispatch and optimal sizing of battery energy storage systems in utility load-leveling operations." IEEE Transactions on Energy Conversion.


Kaye, Thai Doan Hoang Cau and R. J. 2001. "Multiple distributed energy storage scheduling using constructive evolutionary programming." PICA 2001. Innovative Computing for Power - Electric Energy Meets the Market. 22nd IEEE Power Engineering Society. International Conference on Power Industry Computer Applications. Sydney. 402-407.


T. Y. Lee. 2007. "Operating Schedule of Battery Energy Storage System in a Time-of-Use Rate Industrial User With Wind Turbine Generators: A Multipass Iteration Particle Swarm Optimization Approach." 774-782.

L. C. C. Fung. 2000. "Combined fuzzy-logic and genetic algorithm technique for the scheduling of remote area power system." IEEE Power Engineering Society Winter Meeting. 1069-1074.