An Analytical Research and Implementation on Power System Management based on Smart Grid Concept

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Abstract- The advancement in power electronics and digital control technology, the DG systems can be actively controlled to enhance the system operation with improved PQ at PCC. The use of power electronics based equipment and non-linear loads at PCC generate harmonic currents, which deteriorate the quality of power. A converter is being used which can be used both as a rectifier and an inverter. A battery is used as a storage system whichstores the extra energy produced from the grid and supplies it back to the grid when needed. A bidirectional converter is used which can be used both as Homer generates output power productions and power consumptions. The electrical grid of the example represents Utility distribution system. Several feeders are connected to the 25-kV bus of the substation. One of them supplies the power to a community that owns the PV farm and an energy storage system. The grounding transformer provides a neutral point and limits the overvoltage on the healthy phases during a single-phase fault. Based on a given load profile, PV farm output, ESS power rating and capacity, the simulation will give the numberof unavailability for a full year. This sizing study is performed for various locations. The grid-interfacing inverter with the proposed approach can be utilized to inject real power generated from RES to the grid, and/or, Operate as a shunt Active Power Filter.

I. INTRODUCTION

Electric utilities and end users of electric power are becoming concerned about meeting the growing energy demand. 75 percent of total global energy demand is supplied by the burning of fossil fuels. But increasing air pollution, global warming concerns, diminishing fossil fuels and their increasing cost have made it necessary to look towards renewable sources as a future energy solution. there has been an enormous interest in countries on renewable energy for power generation. The market liberalization and government's incentives have accelerated the renewable energy sector growth.

Renewable energy source (RES) distribution level is termed as distributedgeneration (DG). The utility is concerned due to the high penetration level of intermittent RES in distribution systems as it poses a threat to network in terms of stability, voltage regulation and power-quality (PQ) issues. The DG systems are required to comply with technical andregulatory frameworks to ensure safe, reliable and efficient operation of network.

The advancement in power electronics and digital control technology, the DG systems can be actively controlled to enhance the system operation with improved PQ at PCC. The use of power electronics based equipment and non-linear loads at PCC generate harmonic currents, which deteriorate the quality of power.

Current controlled voltage source inverters are used to interface the intermittent RES in distributed system. Recently, a few control strategies for grid connected inverters incorporating PQ solution have been proposed. In an inverter operates as active inductor at a certain frequency to absorb the harmonic current.

But the exact calculation of network inductance in real-time is difficult and may deteriorate the control performance. A similar approach in which a shunt active filter acts as active conductance to damp out the harmonicsin distribution network is proposed. A control strategy for renewable interfacing inverter based on - theory is proposed. In this strategy both load and inverter current sensing is required to compensate the load current harmonics.

The non-linear load current harmonics may result in voltage harmonics and can create a serious PQ problem in the power system network. Active power filters (APF) are

extensively used to compensate the load current harmonics and load unbalance at distribution level. This results in an additional hardware cost. However, in this paper authors have incorporated the features of APF in the, conventional inverter interfacing renewable with the grid, without any additional hardware cost. Here, the main idea is the maximum utilization of inverter rating which is most of the time underutilized due to intermittent nature of RES.
It is shown in this paper that the grid-interfacing inverter can effectively be utilized to perform following important functions:-

1. Transfer of active power harvested from the renewable resources (wind, solar, etc.);
2. Load reactive power demand support;
3. current harmonics compensationat PCC; and
4. Currentunbalance and neutral current compensation in case of 3- phase 4-wire system.

Moreover, with adequate control of grid-interfacing inverter, all the four objectives can be accomplished either individually or simultaneously. The PQ constraints at the PCC can therefore be strictly maintained within the utility standards without additional hardware cost.

II. POWER QUALITY

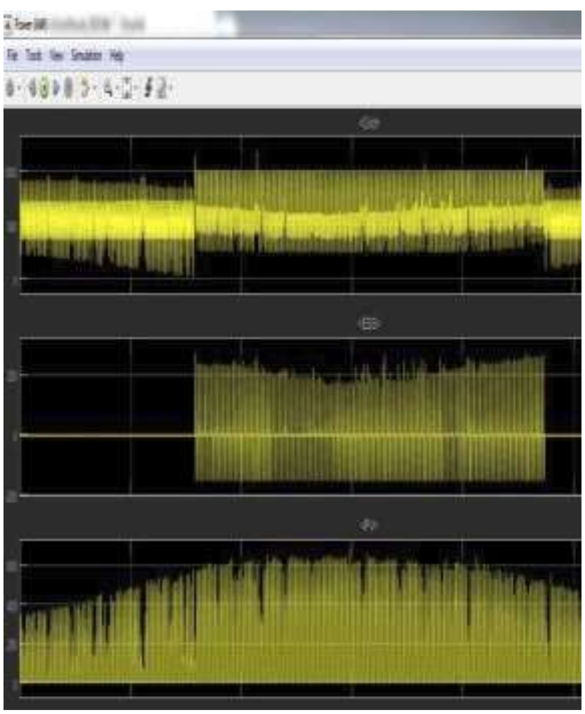
The contemporary container crane industry, like many other industry segments, is often enamored by the bells and whistles, colorful diagnostic displays, high speed performance, and levels of automation that can be achieved. Although these features and their indirectly related computer based enhancements are key issues to an efficient terminal operation, we must not forget the foundation upon which we are building. Power quality is the mortar which bonds the foundation blocks.
Power quality also affects terminal operating economics, crane reliability, our environment, and initial investment in power distribution systems to supportnew crane installations. To quote the utility company newsletter which accompanied the last monthly issue of my home utility billing: „Using electricity wisely is a good environmental and business practice which saves you money, reduces emissions from generating plants, and conserves our natural resources.‟ As we are all aware, container crane performance requirements continue to increase at an astounding rate.
Next generation container cranes, already in the bidding process, will require average power demands of 1500 to 2000 kW - almost double the total average demand three years ago. The rapid increase in power demand levels, an increase in container crane population, SCR converter crane drive retrofits and the large AC and DC drives needed to power and control these cranes will increase awareness of the power quality issue in the very near future.

2.1 Simulations of Smart-Meter using MATLAB with GUI

In order to maintain the feasibility of the system smart meter based GUI model implemented for this purpose. The smart meter model has been programmed in MATLAB. Then the GUI based model “Meter_v2015a” has been developed. Fig demonstrates the model using available data. The variable data input can be placed in the top pane by the user. The figure on the right side of the GUI show the total consumption, solar, wind,biomass output, total production, total sell & buy in based on the real time data shows the demonstration of “Meter_v2015a”.
Demonstrate Sim Power Systems capabilities to simulate an electrical circuit and control system, in pharos mode, for a full-year period in less than one minute of simulation time. Illustrate concepts related to Energy Storage Systems (ESS). Show how to use public solar data time-series (TMY3 files) and how to create typical load profiles.
A simple scenario has been chosen to illustrate one usage of this example: The objective is to determine appropriate sizing (power & capacity) of ESS equipment connected to a 600V community electrical system, in order to prevent the community from purchasing more power than agreed with the Utility Company. Based on a given load profile, PV farm output, ESS power rating and capacity, the simulation will give the number of unavailability for a full year. This sizing study can be performed forvarious locations.

III. DISTRIBUTION POWER SYSTEM

The electrical grid of the example represents Utility distribution system. It consists of a 120-kV transmission system equivalent supplying a 25-kV distribution substation. Several feeders are connected to the 25-kV bus of the substation. One of them supplies the power to a community that owns the PV farm and an energy storage system. The grounding transformer connected at the 25-kV bus provides a neutral point and limits the overvoltage on the healthy phases during a single-phase fault. Its zero-sequence impedance isthree times the value of the grid positive sequence impedance. The Pharos solution of the Powergui block, this grid can be simulated in a very short time even if the simulation period is one year. Pharos solution is the ideal algorithm if you are only interested in the changes to magnitude and phase of all voltages and currents in your circuit. You do not need to solve all differential equations (state space model) resulting from the interaction of R, L, and C elements. You can instead solve a much simpler set of algebraic equations relating the voltage and current phases. This is what the Pharos solution method does at a particular specified frequency (60 Hz in this).



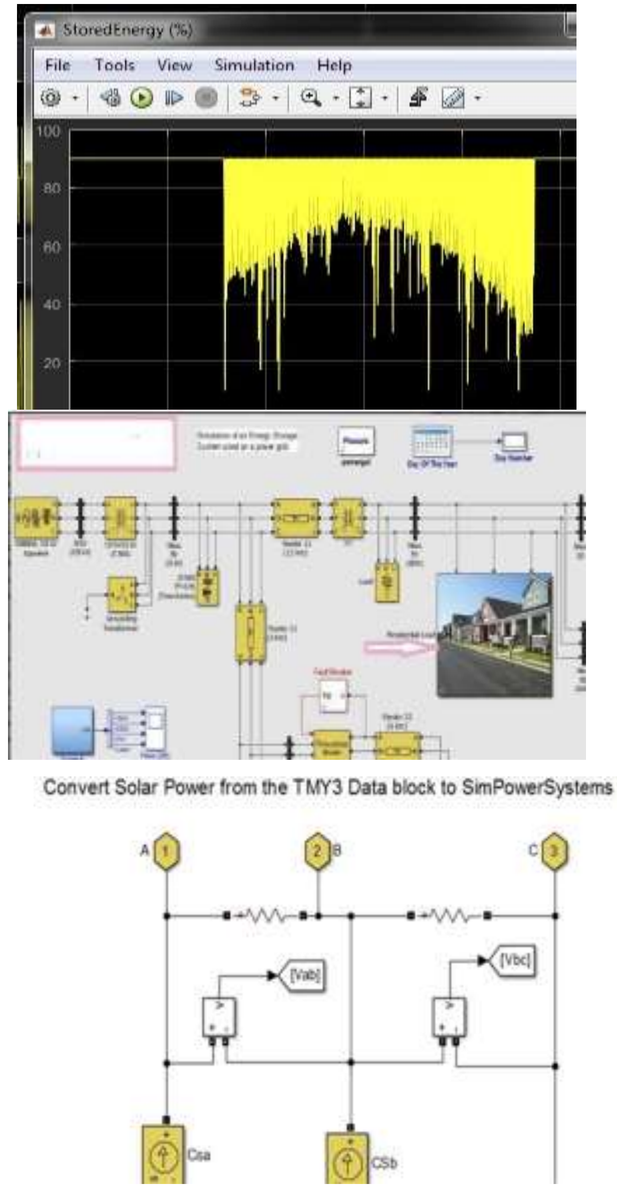


Fig 1 distribution model

A multitude of applications related to energy storage systems and smart grids can be studied and validated using a Sim Power System model such as this ESS demo. Applications could be as diverse as financial energy arbitrage, line congestion mitigation, equipment deferral, solar power smoothing, spinning reserve, voltage support, etc.

In our case, a simple scenario has been chosen to illustrate one usage of this demo: The objective is to determine appropriate sizing (power & capacity) of ESS equipment connected to a 600V community electrical system, in order to prevent the community from purchasing more power than agreed with the Utility Company. Based on a given load profile, PV farm output, ESS power rating and capacity, the simulation will give the number of unavailability for a full year. This sizing study can be performed for various locations.

IV. SIMULATION

The figure on the right shows two day results where the ESS control system determines the power required from the ESS, to avoid exceeding the maximum power allowed from the grid (1000 kW for this simulation)

- On day 91, the ESS was not able to provide the necessary amount of power, and the community has no choice to buy more power from the grid.
- On day 92 the ESS output was sufficient to avoid exceeding the maximum power.

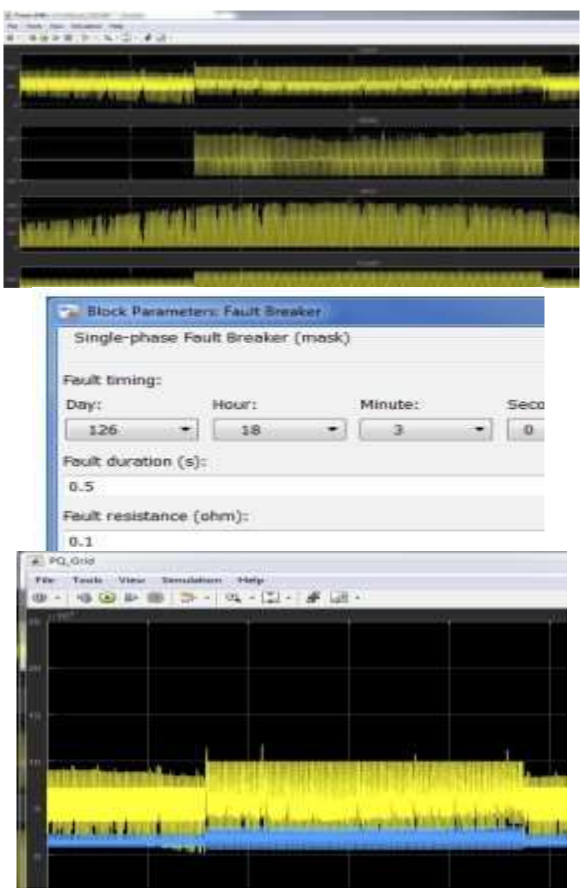


Fig 2: Power calculation

The figure shows a zoom on the transient caused by a fault at Bus B4, at 18h03 on day 126 (May 6th). The Pharos solution produced simulation results to the millisecond precision at the programmed fault timing

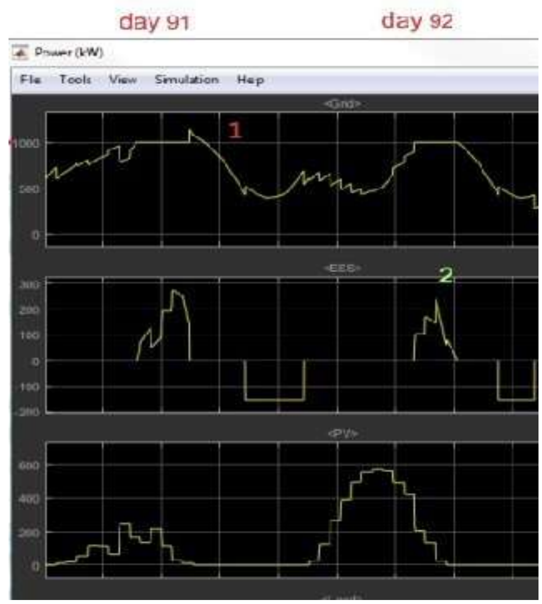


Fig 3: power calculation

RESULT ANALYSIS

A scenario has been chosen to illustrate one usage of this example: The objective is to determine appropriate sizing (power & capacity) of equipment connected to a 600V community electrical system, in order to prevent the community from purchasing more power than agreed with the company. Based on a given load profile, PV farm output, power rating and capacity, the simulation will give the number of unavailability for a full year. This sizing study can be performed for various locations.

V. CONCLUSION

This thesis has presented a novel control of an existing grid interfacing inverter to improve the quality of power at PCC for a 3-phase 4-wireDGsystem. It has been shown that the grid-interfacing inverter can be effectively utilized for power conditioning without affecting its normal operation of real power transfer. The grid- interfacing inverter with the proposed approach can be utilized to:

1. Inject real power generated from RES to the grid, and/or,
2. Operate as a shunt Active Power Filter (APF).

This approach thus eliminates the need for additional power conditioning equipment to improve the quality of power at PCC. Extensive MATLAB/Simu link simulations as well as the DSP based experimental results have validated. Moreover, the load neutral current is prevented from flowing into the grid side by compensating it locally from the fourth leg of inverter. When the power generated from RES is more than the total load power demand, the grid-interfacing inverter with the proposed control approach not only fulfills the total load active and reactive power demand (with harmonic compensation) butal so delivers the excess generated sinusoidal active power to the grid at unity power factor.

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