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Original Article

Power Electronic Innovations in Cyber Physical System

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Abstract: *In this project, a broad overview of the current research trends in power- electronic innovations in Cyber physical systems (CPSs) is presented. The recent advances in semiconductor device technologies, control architectures, and communication methodologies have enabled researchers to develop integrated smart CPSs that can cater to the emerging requirements of smart grids, renewable energy, electric vehicles, trains, ships, internet of things(IoTs), etc. The topics presented in this paper include novel power-distribution architectures, protection techniques considering large renewable integration in smart grids, wireless charging in electric vehicles, simultaneous power and information transmission, multi-hop network- based coordination, power technologies for renewable energy and smart transformer, CPS reliability, transactive smart railway grid, and real-time simulation of shipboard power systems. It is anticipated that the research trends presented in this paper will provide a timely and usefuloverview to the power-electronics researchers with broad applications in CPSs.*

Keywords: *Cyber Physical System, Semiconductor, Control Architectures, Communication Methodologies*.

I. INTRODUCTION

The recent advancements in wide-bandgap semiconductor devices, electric vehicles and locomotives, and a general push from the government agencies worldwide towards renewable energy integration have resulted in a number of advancements in power electronics research. These include, but are not limited to, high efficiency power circuit topologies, sophisticated battery management and charging systems, intelligent power converters, wireless power transfer, internet of things (IoT) devices, etc. A feature that distinguishes the current research from the conventional power electronics is the attempt to seamlessly integrate the cyber layer consisting of control, communication and computing with the physical layer that includes the power semiconductor devices, passive and active circuit components. It is this integration that helps in developing smart power solutions for applications such as IoT, fast charging solutions for electric vehicles, aircraft for urban air mobility, etc. In this paper, a review of the current research trends in power electronics innovations in CPSs [1] is presented.

This is described with reference to several broad application areas such as smart/micro/nano grids, e-mobility, smart energy routing, IoTs, and resilient energy systems. The topics include alternate power distribution architectures, topologies, protection schemes, communication technologies, smartpower components, and reliability of CPS. Fig. 1 pictorially depicts all the sections presented in this paper and maps them to the components of CPS. It must be noted that such a broad collection of research topics that come under CPS has not been presented in literature. This paper is targeted at enabling the research community in the areas of power electronic hardware, control techniques and communication technology (wired/wireless) to look for integrated CPS solutions that can help in developing smart and resilient power converter technologies with the ultimate goal of achieving energy sustainability.

The organization of the paper is as follows. Section II introduces resilient energy CPS. Section III describes a power architecture and protection technology in modern and smart grids. Section IV discusses the recent trends and issues in e-mobility and power and information cotransmission. In Section V, promising methods for coordinated control of power-electronics based network are discussed. Section VI gives an overview of the reliability in CPSs while Section VII describes power topology advances and smart transformer modules. In Section VIII, a transactive approach to cost of electricity reduction in a smart railway grid is outlined followed by a description of real-time simulation for shipboard power systems in Section IX. Conclusions are provided in Section X.

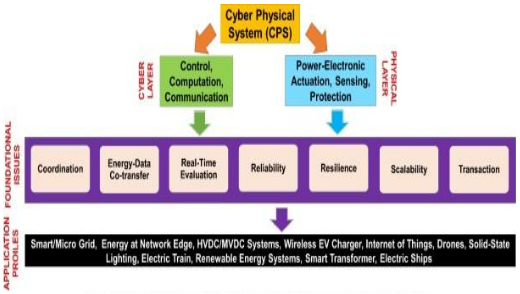


Fig 1. Mapping of topics covered in this paper to the components of cyber physical systems

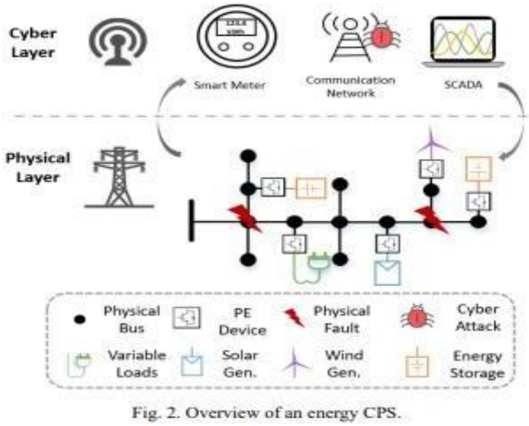


Fig 2.Overview of an energy CPS

example, a variety of system measurements are synthesized at a SCADA to assist in system monitoring, protection, realtime control, and economic dispatch [2]. Recently, the increasing deployment of advanced metering infrastructure, emerging communication networks, and powerful computing units have allowed for an even more wideranging monitoring and remote- control capability for energy systems. Although it is expected that the increasing investment in the cyber layer will make an energy system more resilient to contingencies, many still are concerned that the increasing dependence of system operations on cybernetic technologies might introduce new challenges. First, a malfunction of a cyber-domain component could leadto high-impact physical-domain contingencies. Second, adversaries might exploitor even plant loopholes in the cyber-layer to maliciously maneuver system operations or to steal private and security-related information. In the 2015 Ukraine power grid cyber-attacks, the adversaries corrupted the information system to paralyze the power supply for tens of thousands of customers

II. SYSTEM IMPLEMENTATION

2.1 EXISTING SYSTEM

- This project existing for RF communication system .This system drawback is limited distance.
- This method is not secure.
- The existing system only for load scheduling.

2.2 PROPOSED SYSTEM

- The proposed system load mismatch can be recognizing by the continuous monitoring of frequency as a cause parameter. The embedded controller closely monitoring the frequency behavior of the system.
- whenever it is seen as abnormal the load shedding command can be propagated from the controller through IoT communication and the other end substation can trip off the particular harmful load immediately.
- By doing this way, this project is protecting the generators from overloading effects and also the grid is maintained at healthy by evicting out the heavy loads.
- This project control voltage & frequency method. The control signal through IOT.

2.3 BLOCK DIAGRAM

Customer end

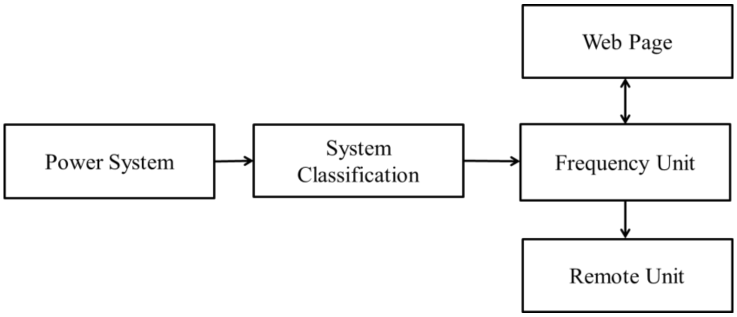


Fig 2.1 block diagram

IOT End

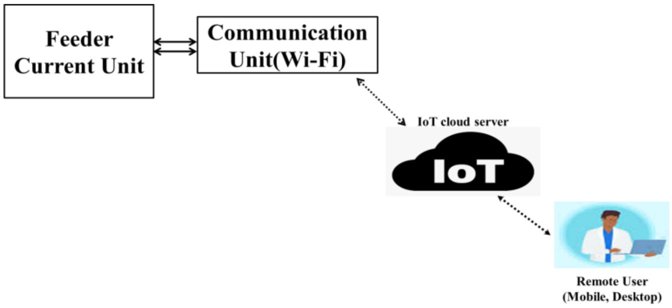


Fig 2.2 IoT Block Diagram

2.4 ADVANCES IN HARDWARE AND POWER-CONVERTERTOPOLOGIES

2.4.1 Power Electronic Converters for Solar Plus Storage Systems

The solar-plus-storage system is a typical configuration for a DER generation system, where a battery energy storage system (BESS) can be integrated with a solar PV system to mitigate the irregularities of the PV system and improve system reliability In a dc-coupled solar plus storage system, both the PV and BESS are connected to a common dc bus to supply energy to a grid-tied inverter or directly to the loads in a microgrid. A bidirectional multiport dc–dc converter is desirable to achieve power transfer among the PV arrays, BESS, and the common dc bus. Among various solid-state transformer (SST) topologies, the triple-active-bridge (TAB) converter , where three dc–ac converters are coupled through a three-port transformer, can enable galvanic isolation and transfer power among three dc ports with fewer components. Moreover, similar to its two-port counterpart, i.e., the dual-active-bridge (DAB) converter, the TAB converter can operate at the zero-voltage-switching mode to reduce switching losses. Thus, the TAB converter inherently satisfies the needs of the solar plus storage system.

Compared to the conventional system configuration, the TAB converter-based solar plus storage configuration enables integration at the converter level, which will provide a faster dynamic response and improve system robustness, as a centralized controller can adjust the power distribution between the PV port and BESS port rather than control ling power through communication between different dc–dc converters . To increase system efficiency and power density, SiC devices have been adopted in the TAB design. Fig. 3.2 shows the test setup of a 150-kW TAB system developed by the University of Arkansas using 1.7-kV 635 SiC power modules.

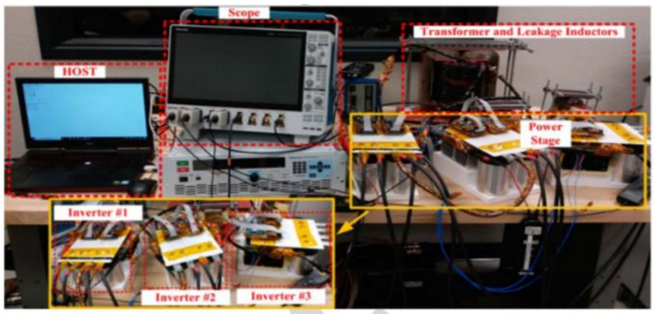


Fig. 2.3. Test setup of a 150-kW TAB converter for solar plus storage systems.

For residential applications, various power router designs are proposed to provide solar plus storage solutions. For instance, a power router is proposed in , which has a PV terminal, a BESS terminal, an isolated dual-half-bridge (DHB) converter, and a split-phase inverter for load connection. To prevent the overgeneration at the PV terminal in the islanded mode, the RPR system can operate with limited power point tracking. In addition, the RPR can provide grid support, e.g., compensate reactive power and phase imbalance.

In addition to the enhanced electrical performance reliability described above, the RPR described has been further enhanced with advanced cybersecurity features that provide enhanced resiliency and availability . This includes encryption, authentication, and protections that span both hardware and firmware in addition to communications that provide added assurance that solar plus storage systems can remain safely in operation—even in the event of a cyberattack. These measures address detection and mitigation methods against the attack surface of the power electronics device as a whole—preventing compromise and physical damage. These cyber-hard-by-design approaches cost relatively little in terms of additional hardware components but provide great benefits 668 for the RPR and grid.

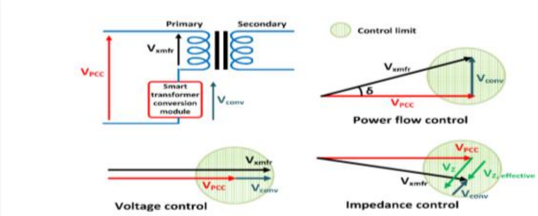


Fig.2.4. Enhancement of substation transformer to perform advanced system support.

2.4.2. Smart Transformer Conversion Module

The current U.S. power network is undergoing revolutionary structural and functional changes with the proliferation of renewable, converter-based DERs, and increased use of active loads. Advancements in digital sensor networks, data analytics, and communication technologies add new challenges to power system control, grid visualization, operation, communication bandwidth, and physical and cyber securities, with a resulting threat to grid resilience and reliability.

One of the most strategic power equipment, in the legacy power network, is the substation transformer. It is important to transition traditional transformers into smart transformers that can perform a variety of advanced grid support functions. While the concept of smart SSTs is being widely recognized, their respective lifetime and reliability raise serious concerns with power utilities, thus hampering the replacement of traditional transformers with fully electronic SSTs. It is, therefore, proposed to introduce smart features in conventional transformers utilizing simple, cost-effective, and easy to install modules, which is highly desirable. These include voltage regulation, voltage and impedance balancing, harmonics isolation, voltage ride through (VRT), blocking dc in ac networks, and the prevention of the critical grid assets from natural or man-made disturbances, as shown in Fig.3.3.

Adding more controllability in a traditional power trans former does provide greater flexibility and mitigation features in power network operation, microgrid forming, and mitigation, but it also provides challenges in terms of vulnerabilities in terms of system protection, unintending islanding, reliability, and cybersecurity. Additional requirements in terms of localized self-healing and controllability from local system parameters are essential in moving forward with more advanced power system control and mitigation using AI.

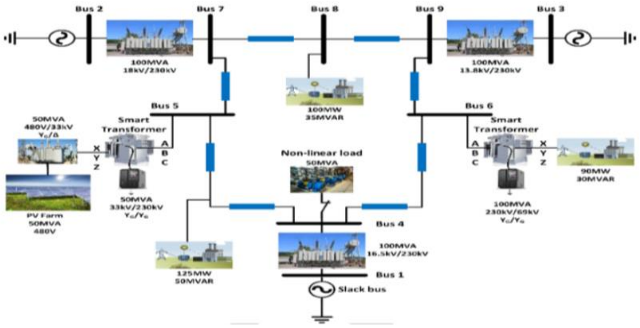


Fig 2.5. IEEE nine-bus system depicting hybrid smart transformers with high penetration of intermitted resources and active loads .

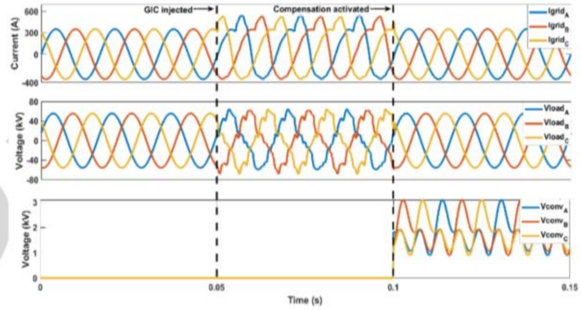


Fig. 2.6. Mitigation of transformer saturation due to unwanted dc injection using hybrid smart transformers.

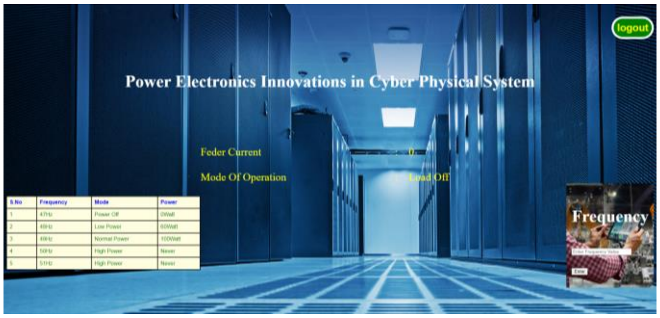
This power electronic-enhanced hybrid transformer concept was evaluated for several applications of these grid support and mitigation functions on a nine-bus power system with, as shown in Fig. 3.4. The HIL simulation results of some of these functions are plotted in Fig. 3.5.

III. RESULTS

Home page

Fig 3.1 login page

Mode of operation-1



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Feder Current 0

Mode Of Operation Load Off

S.No	Frequency	Mode	Power
1	47Hz	Power Off	0Watt
2	48Hz	Low Power	60Watt
3	49Hz	Normal Power	100Watt
4	50Hz	High Power	Never
5	51Hz	High Power	Never

Fig 3.2 load off

Mode of operation-2

Power Electronics Innovations in Cyber Physical System

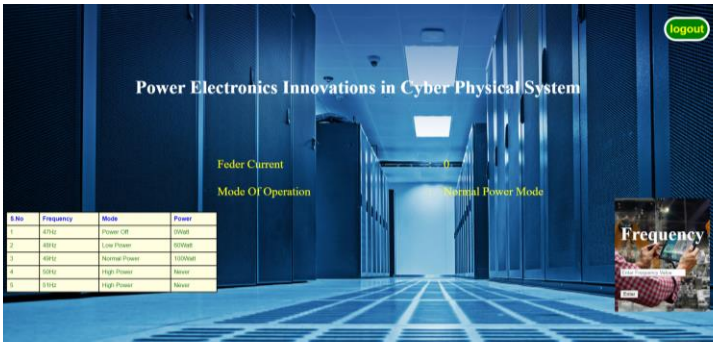
Feder Current 0

Mode Of Operation Low Power Mode

S.No	Frequency	Mode	Power
1	47Hz	Power Off	0Watt
2	48Hz	Low Power	60Watt
3	49Hz	Normal Power	100Watt
4	50Hz	High Power	Never
5	51Hz	High Power	Never

Fig 3.4 low power mode

Mode of operation-3



Power Electronics Innovations in Cyber Physical System

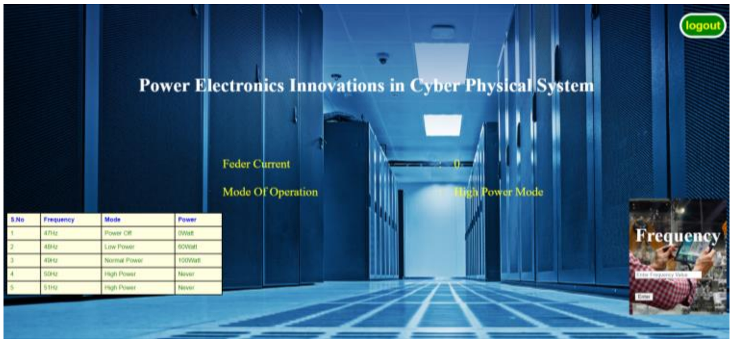
Feder Current 0

Mode Of Operation Normal Power Mode

S.No	Frequency	Mode	Power
1	47Hz	Power Off	0Watt
2	48Hz	Low Power	60Watt
3	49Hz	Normal Power	100Watt
4	50Hz	High Power	Never
5	51Hz	High Power	Never

Fig 3.5 normal power mode

Mode of operation-4



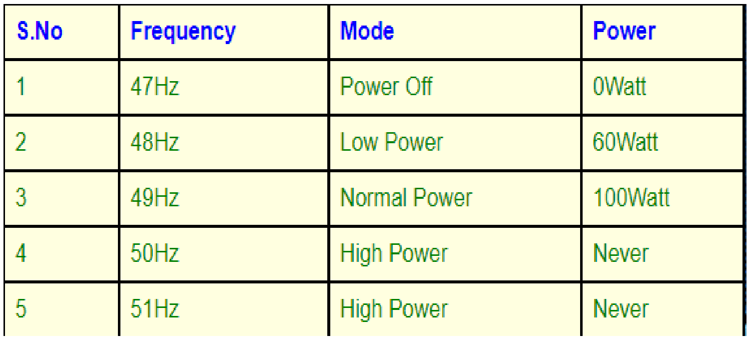
Power Electronics Innovations in Cyber Physical System

Feder Current 0

Mode Of Operation High Power Mode

S.No	Frequency	Mode	Power
1	47Hz	Power Off	0Watt
2	48Hz	Low Power	60Watt
3	49Hz	Normal Power	100Watt
4	50Hz	High Power	Never
5	51Hz	High Power	Never

Fig 3.6 high power mode



S.No	Frequency	Mode	Power
1	47Hz	Power Off	0Watt
2	48Hz	Low Power	60Watt
3	49Hz	Normal Power	100Watt
4	50Hz	High Power	Never
5	51Hz	High Power	Never

Fig 3.7 Frequency Table

IV. CONCLUSIONS

This review covers a broad range of topics involving the confluence of power electronics and CPSs encompassing plurality of emerging applications. It provides an overview on multiple research issues and challenges in these application areas and the solutions that are being pursued. To begin with, the issue of vulnerability of CPSs based on power-electronic converters to cybernetic technologies and the evolving need for resilience to such vulnerabilities have been introduced. On a similar note, reliability of powerelectronic systems that form the backbone of energy CPSs needs careful consideration and incorporation of emerging data- centric methodologies, as have been captured in this project.

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