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A review on Construction and Performance Investigation of Three-Phase Solar PV

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Abstract: The levelized cost of electricity (LCOE) of solar photovoltaic (PV) systems is continuously declining in many countries, which is largely responsible for the current geometric increase in the global deployment of PV modules at utility-scale and residential roof-top systems. Other factors contributing to this trend are the modules' affordability, scalability, and long-term warranty. Furthermore, as the world's energy portfolio continues to transition towards cleaner energy technologies, PV adoption is anticipated to maintain this increasing trend. Nevertheless, during outdoor deployment, the PV modules are subjected to a broad variety of climatic conditions, regardless of the kind, material, and component technology. The modules are frequently exposed to intense chemical, photochemical, and thermo mechanical stress under these hostile environmental conditions. These circumstances, in addition to manufacturing flaws, significantly increase the ageing rate and faults of PV modules. This research looks at the application of Unified Power Quality Conditioners (UPQC) to reduce grid power quality issues and harmonics caused by non-linear loads. In this work, photovoltaic (PV) and battery energy storage systems (BESS) assist the UPQC. In most cases, the load receives its active power from the PV system. On the other hand, the BESS kicks in and supplies electricity if the PV is unable to do so, particularly during the longer-lasting voltage disruption. Due to its considerable dependence on the environment and instability, a hybrid PV-BESS system is more dependable than a solo PV-UPQC system.

Keywords: LCOE, Solar Photovoltaic (PV), Unified Power Quality Conditioners (UPQC), Battery Energy Storage Systems (BESS), Utility-Scale, Residential Roof-Top Systems

1. Introduction

Two power electronic inverters coupled by a shared DC connection form the basis of the UPFC. To match the voltage levels between the power system and the power electronic inverters and to isolate the UPFC, two transformers are utilised. The transmission cable is linked to one of the inverters. The voltage generated by the series-connected inverter may be adjusted in terms of both phase angle and magnitude. As a result, the transmission line can receive actual as well as reactive power from this inverter. Although it may also function as a stand-alone VAR compensator, the second inverter's primary function is to supply the actual power needed by the series inverter. Consequently, the transmission line's actual and reactive power flow may be managed by the UPFC. The DC side may be divided so that the two VSIs can operate separately. To control the voltage magnitude at the connection point, the shunt inverter acts as a STATCOM in such scenario, producing or absorbing reactive power. Operating as an SSSC, the series inverter produces or absorbs reactive power to control the current flow, which in turn controls the power flow on the transmission line. Because actual and reactive power may be independently controlled, the UPFC can be utilised to enhance power quality. A two-bus system is modelled and simulated using UPFC in this proposed work. Additionally, a 14-bus system with and without UPFC is modelled and simulated. After examining the actual and reactive powers, it was found that the real powers rose as the injection angle increased. With the shunt voltage injection, the reactive power rises. For UPFCs based on PWM inverters, SVM inverters, and MLIs, Simulink models have been built. These three examples' outcomes are contrasted. To enhance the system's voltage profile, the Multiple and Distributed Dynamic Voltage Restorer (DVR) idea is presented.Both with and without UPFC, the IEEE 30 bus system is simulated and modelled. Investigations are done on the reactive and actual powers. By adding a second load, voltage sag is compensated for, and it is shown that the UPFC reduces voltage sag.

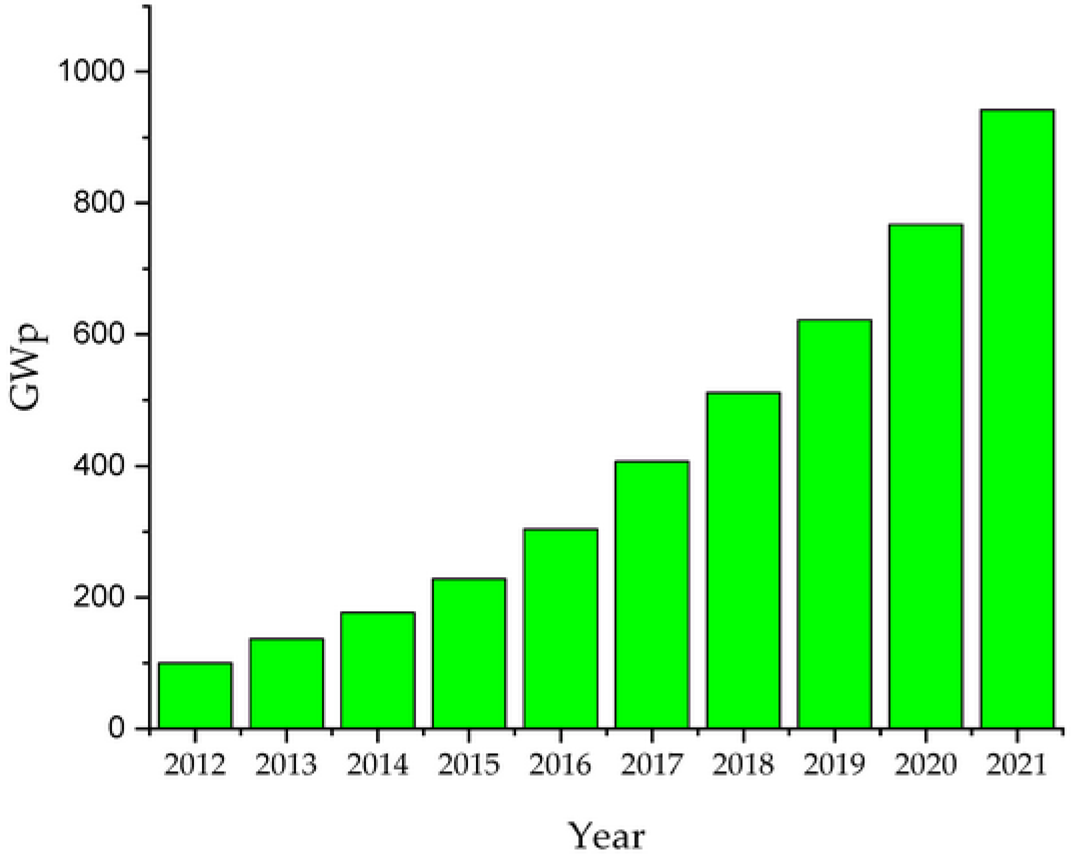

Fig 1: Evolution of PV installations over the past decade

Renewable energy sources, such as solar and wind energy technologies, are acknowledged as affordable and sustainable solutions. They offer clean energy options that significantly lower ecological issues worldwide, especially CO2 emissions. By 2025, solar and wind technologies are expected to dominate the energy landscape, with 60% of capacity expansions coming from solar energy generation. This estimate is quite likely to come true if the problems with accessibility, dependability, and performance are consistently tracked down and fixed. The installation of solar photovoltaic (PV) modules has grown geometrically in recent years, primarily because of their well-known affordability, scalability, and long-term warranty, as well as and this is the most significant the ongoing decline in the levelized cost of electricity (LCOE). When comparing solar and wind power systems to nuclear technology, coal, natural gas, etc., the LCOE basis shows that the former is more costly. When compared to other technologies, the fuel cost for solar and wind power is zero for the LCOE calculation. In comparison to other traditional technologies like gas, nuclear, coal, etc., the cost of solar and wind power has continuously decreased, according to an LCOE estimate analysis for different energy generating technologies. Despite the fact that it took over 60 years to achieve 100 GW of solar energy output by 2012, the National Renewable Energy Laboratory (NREL) announced in 2021 that 939 GW had been attained. PV energy generation is now the energy source with the fastest rate of growth in the world. The global cumulative PV installed capacity expressed in GigaWatts peak is shown in Figure 1.

2. Literature Review

In late 80's, Performance Monitoring, Evaluation & Analysis of a PV system has gained importance giving

Way to new Standards & Procedures for whole process. This has introduced IEC 61724:1998 – Photovoltaic system performance monitoring Guidelines for measurement, data exchange and analysis. This standard describes general guidelines for the monitoring and analysis of the electrical performance of PV systems. This standard recommends procedures for monitoring of energy related PV system characteristics such as in-plane irradiance, array output, storage input and output, power conditioner input and output for the exchange and analysis of monitored data and to assess the overall performance of PV systems both stand-alone and grid-connected. Since then researchers in many countries have authored publications providing basis for intensive research in this field.

L. Moore et.al. have described their 5-year experience of 4.9MW PV plant at Arizona public service,

AZ. It was observed that compared to fixed latitude systems, energy production was 23% and 37% higher for horizontal and tilted tracking respectively. Average annual O & M cost is 0.35% of the initial system cost.

L.Moore et.al. have also presented 5-year experience of 5MW PV plant at Tuscan Electric Power, Tuscan, AZ. This paper presents an assessment of operating experience including performance, costs, maintenance and plant operation over 5-year period. Annual average capacity factor for all systems over the period was 19.5%. Average annual O & M cost is 0.12% of initial system cost. The mean time between unscheduled maintenance events per system is 7.7 months of operation.

U. Jahn et.al. presented operational performance results of grid-connected PV systems in Germany. Performance of 235 PV installations in Germany and 133 PV installations in other countries were compared and discussed. Older installations were found to be on lower side of energy yield with average mean of performance ratio as 0.65 and the newer installations had an average mean performance ratio as 0.74. For Germany, a significant rise in PV system performance was observed for new PV installations due to higher component efficiencies and increased availabilities. Dominating performance constraints were poor reliability of inverters, long repair times and shading problems.

U. Jahn et.al. presented results of performance of 334 PV installations across 14 different countries. Switzerland showed a higher PR (>0.80). For Japan, lessons were learnt from monitoring programs and performance improvement was observed. It was observed that system availability indirectly indicates the reliability of the system. In the same way Performance Ratio also is affected by the reliability. Low PR was due to high failure rate. It was further observed that the system availability is generally higher for systems which are intensively monitored.

O saheed Ismail et.al. presented the performance assessment of installed PV of Oke-Agunla in Nigeria. The result showed that only 14.52% of 4.5KW installed for a village of 150 households was utilized. This under utilization was because of poor maintenance, system malfunctioning, lack of technical know-how and inadequate training of village personnel causing an inefficient PV systems operation.

J.D.Mondol et.al. presented the impact of array inclination and orientation on the performance of PV plant. Incident insolation and PV outputs were maximum for surfaces inclined at 30: due south and minimum for surfaces at 90:. For horizontal surface monthly variations in the system parameters were significant over a year. TRNSYS simulation package was used to validate the above results.

Eltawil.M et.al. emphasized the importance of grid connected PV systems regarding the intermittent nature of renewable generation. A review on expected potential problems associated with high penetration levels was presented. The need for reliability, life span and maintenance needs during long term operation of PV system was reviewed.

R. Hosseini et.al. presented the improved performance of PV system by improving the constraints like reflection of sun's irradiation and temperature of PV modules and hence increasing the electrical efficiency by 33% by decreasing the module temperature by 18.

Lacour Ayompe et.al. presented the results of performance of 1.72KWp PV system in Ireland monitored in 2008-2009. Performance parameters like average solar insolation, ambient temperature, PV module temperature, wind speed were analyzed. In addition to these final yield, array yield, reference yield, performance ratio, capacity factor, module and system efficiencies, various losses were detailed appropriately.

3. The Torque Ripple Minimization Methodology For Bldc Motors

(i) Shunt Converter Control Strategy- The voltage of the dc link capacitor and the UPFC bus voltage/shuntre active power are managed by the shunt converter of the UPFC. The shunt converter voltage in this instance may be broken down into two parts. When it comes to the UPFC bus voltage, one component is quadrature and the other is in phase. The UPFC bus voltage and the dc link capacitor voltage are controlled simultaneously thanks to the use of a decoupled control mechanism.

(ii) Series Converter Control Strategy- Real and reactive power flow in the transmission line may be simultaneously controlled by the UPFC's series converter. In order to do this, the voltage injected by the series converter is split into two halves. The transmission line's actual power flow is controlled by a quadrature-injected component, which is one of the series-injected voltage's components. This tactic is comparable to a phase shifter. The reactive power flow in the gearbox line is managed by the in-phase component. This tactic is comparable to changing a tap.

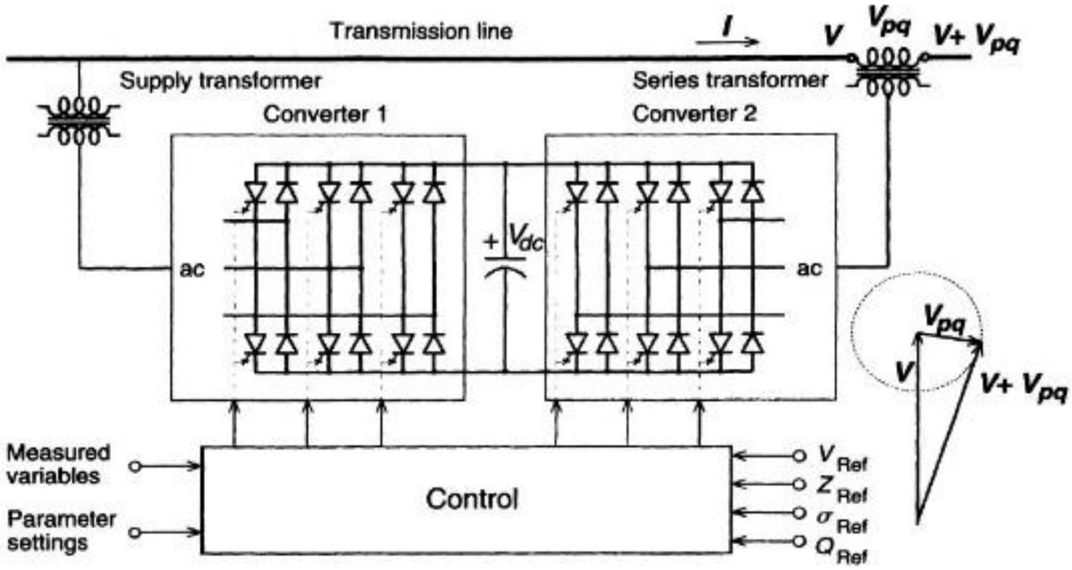

Fig 2: UPFC Connected to a Transmission Line

(iii) Basic Circuit of UPFC- As seen in Figure 2, the Unified Power Flow Controller is made up of two switching converters that, in the implementations under consideration, are voltage sources inverters. The common dc connection for these inverters, designated as "Converter 1" and "Converter 2," is supplied by a dc storage capacitor. This configuration serves as the perfect power converter, allowing actual power to freely flow between the two ac terminals to either create or absorb reactive power at the respective ac output terminal. At the common dc connection, Converter 1's primary job is to provide or absorb the actual power that Converter 2 requests. By using a shunt connected transformer, the dc link power is transformed back into ac and linked to the transmission line. If needed, Converter 1 can additionally produce or absorb adjustable reactive power, which enables it to supply the line with independent shunt reactive compensation. The corresponding reactive power exchanged is supplied or absorbed locally by Converter 2, meaning it does not flow through the line. This is significant because the real power negotiated by the action of series voltage injection through Converters 1 and 2 has a closed “direct” path back to the line. In essence, this injected voltage may be thought of as a source of synchronous ac voltage. This voltage source is passed through by the transmission line current, which causes a genuine and reactive power exchange with the AC system. The inverter transforms the real power exchanged at the ac terminal that is, at the insertion transformer terminal—into dc power, which manifests as either positive or negative real power demand at the dc link. The inverter produces the reactive power exec terminal inside.

4. Analytics Models Driven By Data For Pv Performance And Reliability Evaluation

Proper and accurate PV degradation and failure diagnosis and classification models are required to quickly and accurately identify and classify degradation and defects modes and signatures, as it is becoming more difficult for skilled personnel to analyse and classify the various degradation and defect modes and signatures using traditional visual inspection methods. This will help to significantly improve the performance of PV systems, including power capacity and module lifespan, reliability, and overall safe operation. The additional disadvantage of conventional approaches, in addition to the need for human skill for calculation and analysis, is their non-linearity and computational complexity, high mistake rates, impossibility in big PV systems, and significant labour needs. Therefore, sophisticated and useful models for diagnosing PV deterioration are desperately needed. Identifying and classifying the deterioration modes so that appropriate preventive actions may be quickly set up is the primary goal of efficient diagnostic models. Because of their efficiency and performance (low calculation time and high processing capacity as compared to other approaches), data-driven analytical techniques like ML and DL models are consistently proving to be viable choices. Furthermore, the future status of events that occur in systems may be predicted with the use of ML and DL models. Because ML and DL approaches may be used for PV module performance and degradation evaluation in the lab, throughout production, and during outdoor deployments, they have garnered the interest of many stakeholders in PV degradation and reliability studies in recent years. As a result, methods for tracking, forecasting, identifying, and categorising different PV degradation threats are often presented in recent research. Due to the massive installations of PV modules, particularly in utility-scale systems, and the abundance of available datasets, machine learning (ML) and deep learning (DL) models are able to quickly learn and identify irregular patterns, as well as draw meaningful conclusions about the prediction, detection, and classification of PV degradation features.

(i) Dataset Generation Phase- Thanks to technological advances, writers have been able to create datasets for analysis using non-destructive imaging techniques such I-V, EL, PL, UV fluorescence imaging tools, and/or EPM tools. To anticipate, identify, and categorise PV degradation threats, classifier inputs consisting of pictures and/or electrical parameter measurements (which may include characteristics like ISC, VOC, IMP, PMP, VMP) are commonly employed. Generally, compromised or malfunctioning parts of the PV module, such the cell, encapsulants, and connectors, etc.

(ii) Feature Engineering/Optimization Phase- The big dimension feature datasets (captured imagery and EPM) that are produced are ideally unsuitable for use as input for the classifier(s) because they include redundant features that would drastically increase the computing time of the classifier and decrease the accuracy of its classifications [79]. Preprocessing the datasets is therefore typically required for effective classification and prediction. Several feature engineering strategies have been presented by various authors in recent literatures to improve the performance of PV deterioration modes prediction and classification during the dataset(s) preparation phase. Feature vector size may be decreased, superfluous features can be cleaned out, and the performance of the classifiers can be enhanced by using a variety of feature engineering approaches, from feature selection and reduction to optimisation.

(iii) Classification/Detection/Prediction Phase- In recent times, data-driven analytic models have gained more credibility as viable approaches for efficient PV deterioration and defect detection and classification tools because to their capacity to learn on their own, adapt to changes, and operate without needing to be pre- or re-programmed. PV degradation and defect detection and classification studies have made use of a variety of ML and DL models, including Support Vector Machine (SVM), Decision Tree (DT), K-nearest neighbours (KNN), Random Forest (RF), Naïve Bayes (NB), and Neural Networks, as documented in recent research. NB, DT, and SVM are popular supervised learning algorithms that are utilised for classification jobs because they are easy to use and use little memory.

5. Conclusion

To improve protection, UPFC-based controllers like the POD and d-q controllers are successfully installed on the power system. It encourages effective power compensation outcomes. Comparing the system with UPFC to the one without, there is a noticeable improvement in the actual and reactive power flow via the gearbox line. the thermal capacity of lengthy transmission lines, which may be optimised with the use of a unified power flow controller. UPFC improves the transmission line's capacity, which benefits the power system.

The performance of PV modules deteriorates over time, particularly in outdoor circumstances, as these studies show. Our study provides an analysis of previous research studies that have examined the performance, dependability, and deterioration of solar PV systems, with a focus on data-driven analytics. As silicon photovoltaic panels, which presently rule the worldwide market, have been the subject of the majority of research studies published in recent literature. This research project therefore focuses primarily on crystalline silicon modules. A thorough examination is conducted on the many technical flaws and degradation difficulties, as well as the characterisation methodologies used in recent literature. Current degradation measurements and characterisation techniques that are widely employed for the investigation of important degradation modes in recent literatures include the I-V curve and Sun-Voc tracing methods, imaging techniques such as EL, PL, and UV fluorescence techniques. The study included a thorough discussion and comparison of these methods. Visual inspection, and particularly imaging techniques, give qualitative insights on the categorization of deterioration modes and signs, while EPM methods provide data about electrical characteristics with less information on damaged components.

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