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Title	**:**	Integration of Renewable Energy Sources in Microgrid with Power Quality Improvement Features
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ABSTRACT

The growing concern about the lack of energy resources and harmful impacts of fossil fuel emissions has initiated the requirement of new, reliable and cleaner sustainable energy sources. So, the solar photovoltaic system and wind power system are fastest developing sources among the different renewable energy sources. The development in distribution generation technology such as wind turbine, photovoltaic system, and advancement in power electronics circuitry, increase in cost of fuel, energy demand and the depletion of fossil fuels are making the power sector to use these renewable energy sources as an alternative energy sourcefor better stability, reliability and power quality. Hence, the sustainable microgrid primarily powered by renewable energy sources is a recent concept built to fulfill the pledge of delivering reliable power supply for upcoming power systems. Renewable energy sources can be interfaced through the distributed power generation modules with microgrid structure. Depending on the situations,microgrid can be operated either with the main grid or in island mode.

The solar irradiance and wind speed data are prerequisites for designing and sizing of solar and wind energy systems including the site selections for their respective solar and wind power plants. Unfortunately these data points are not available for most of Indian locations. Therefore, regression models for assessment of global solar radiation using different meteorological parameters such as mean sunshine duration per hour, temperature, relative humidity, and rainfall have been developed in this work. The performance of the model is determined on the basis of statistical indicators like correlation coefficient (R), coefficient of determination (R2), root mean square error (RMSE), mean percentage error (MPE) and mean bias error (MBE). The correlation using different variables given above, for estimating global solar radiation incident on horizontal surface incorporating all the above-mentioned parameters are found to be accurate. Further, fuzzy and model predictive based models for predicting the wind power for selected stations in India are presented. The meteorological parameters like relative humidity and vapour pressure and the geographical parameters like latitude, longitude, altitude of the selected location are defined as input parameters. Based on the computed data, fuzzy logic and model predictive system are used to predict the wind power at five different Indian stations that have different geographical and climate conditions. Analysis shows that fuzzy based system is easy to implement.

The proposed work also presents economic feasibility of Grid-Connected hybrid energy system to electrify the residential, commercial and industrial areas in Ramapuram, Chennai, India. In this study, ENNORE thermal power station, Chennai is considered to reduce the carbon emissions by the integration of solar power system and wind power system to the grid and subsequent reduction in the units generated from this plant. By implementing the grid-connected hybrid energy system for power generation, the results indicate that the proposed system is well suited for Ramapuram, Chennai, India based on overall cost. It is also found that the coal-based power plant generates a huge amount of carbon footprints and it can be reduced with the replacement of it with the easily available renewable energy sources i.e. solar and wind energy systems. Therefore, the results of study encourage the use of the solar and wind energy systems to electrify the residential, commercial and industrial areas in India. This work also presents the feasibility analysis of net metering implementation in residential buildings in Ramapuram Chennai, India. The analysis shows that the lower payback period and the annual savings in electricity bill are achieved. It is also found that the hybrid energy system with net metering scheme shows great potential to customer-related benefits, electric utility allied welfares and environmental benefits.

The proposed work also presents an analysis and design of a sustainable microgrid primarily powered by renewable energy sources with dynamic performance improvement. The hybrid energy system comprises a solar energy system, wind energy power system, two-level boost converter, and the three-phase inverter supplying power to the utility. The fuzzy-PI controlled hybrid energy system with advanced random pulse position modulation technique (ARPPWM) for controlling the switching pattern for the three-phase grid-connected voltage source inverter has been designed. Using Matlab/Simulink, the system is designed and simulated to detect the practical issues involved in the control and operation of the sustainable microgrid system based on solar and wind energy sources. So, the proposed technique reduces the grid-connected hybrid energy system complexity and harmonic distortion. Furthermore, it is realized that fuzzy-PI controlled hybrid energy system has faster transient response and better performance in comparison with the PI control system. In addition, the lower values of ISE, ITSE, and ITAE show that the proposed fuzzy-PI controller has quick transient response and tracks the exact reference current effectively. Besides, in order to improve the dynamic performance of the hybrid energy system, a current injected control loop (CICL) acting to boost up the calculation of the inverter current references is also proposed. Hence, an improvement in the dynamic response of dc-bus voltage and inverter currents are achieved. The feasibility and helpfulness of the proposed system have been successfully assessed with numerous simulation studies.

To achieve superior harmonic reduction using hybrid energy generation, advanced fuzzy current and voltage controlled technique are also proposed in this work. Using Matlab/Simulink, control and design of both the dc/dc converter and three-phase inverter are presented. It shows that the proposed fuzzy controlled technique can decrease the number of active and passive filters in the microgrid hybrid energy system. Hence, the proposed scheme offers outstanding performance for overcoming the voltage and current distortions. The simulation model of the proposed system is developed in MATLAB/Simulink environment and tested for the proposed control technique performance. The obtained results confirmed that the harmonic distortion level satisfies international standards. Moreover, in order to further analyze the usefulness of control scheme, a simulation case for changing the gains of the PI controller is done and the value of THD level is taken for every case. It is found that the proposed strategy provides better results in comparison with the PI controller and offers a stable operation when the hybrid energy system is deployed.

In this work, the model predictive control scheme is also proposed for a three-phase inverter circuit and it uses a model of the system to estimate the predictions of future values of the system variable for a provided voltage sequence. The proposed system consists of a two-level boost converter with the three-phase inverter circuit, where one controls the wind and solar power, whereas another is used for grid integration. The scheme aims to: reduce the disturbance in the output voltage of two-level boost converter, control the output voltage of the three-phase inverter, and compensate the wind speed and solar irradiance changes and to increase the power quality of the system. Additionally, the cosine firing angle scheme is used for controlling the output voltage of two-level boost converter. Using the model predictive control with 1 step prediction, 2 steps prediction and 3 steps prediction considering the same vector applied in next interval for controlling the output of three-phase inverter circuit, the simple solution is proposed to enhance the power quality of the system. Furthermore, results obtained from model predictive based control are compared with fuzzy-PI based control and found within desired limits. It is also found that the proposed model predictive control scheme has many benefits as compared to a fuzzy logic control scheme such as fewer calculations, lesser cost due to reduction in filter size, increased reliability, and low harmonic distortion. Therefore this control technique is very effective for integration of renewable energy sources to microgrid as well as the main grid.

Hence, renewable energy-based microgrid system will play an important role in fulfilling the future energy demands of the world in general and especially in developing countries like India having huge power requirement. These renewable energy sources based microgrid systems in addition to being environment friendly will provide low-cost electricity with greater reliability. This is the one way to cope up with the energy crisis being faced by the world today. Besides, if renewable energy generation is not used then carbon footprints increase every year. This is harmful to the environment, hence renewable energy sources are used to reduce the emission. Further, to achieve superior harmonic reduction using hybrid energy generation, advanced controlled techniques can be used. Therefore, an idea for integration of renewable energy sources to microgrid with power quality improvement features has been provided.