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Residential Community Load Management Based on Optimal Design of Standalone Hybrid Renewable Energy Systems with PV wind Battery by Implementing Model Predictive Control.

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Abstract— Micro grids being an important entity in the distribution system, and to get their full advantages by incorporating maximum distributed generation, standalone hybrid renewable energy systems (HRESs), being environmentally-safe and economically-coefficient, are considered as the promising solution to electrify remote areas where the grid power is not available. In this work, a techno-economic investigation with an optimal design of HRES is presented to the domestic electricity need for a residential area of the district in the Province of Baluchistan, Pakistan. Nine case studies based on PV/wind/diesel/batteryare analyzed based on net present cost (NPC), cost of energy (COE), and emission to decide the feasible solution. HOMER tool is utilized to accomplish modeling and simulation for economic analysis and optimal sizing. Simulation results demonstrated that HRES with PV-wind-battery is the most viable option for the specked area, and the optimal sizing of components are also obtained with $ 28,620 NPC and $ 0.311/kWh COE which shows 81.65 % reduction in cost and 100 % preserving in toxic emission while fulfilling 100 % energy demand with 67.3 % of excess energy.

Furthermore, MATLAB/Simulink modeling for the optimally designed system is built for technical analysis while its effectiveness is proved by keeping dc and ac buses voltage constant, safe operating range of battery state of charge (SOC) with active power balance between HRES components, as well as ef cient ac voltage quality, regardless of generation disturbances and load uctuations. The output signal has total harmonic distortion (THD) of 0.30%as compared to 5.44%with the conventional control scheme. The novelty lies in the sequential application of both HOMER and MATLAB simulations of the proposed HRES model and validation of the proposition for the studied area; by using and implementing model predictive control (MPC) of a inverter.

INDEX TERMS:Distributed power generation, energy management, control set model predictive control (FCS-MPC), design optimization, micro grids, dc-ac power converters, voltage control, energy conversion, energy resources, solar energy, wind energy, energy storage, maximum power point tracker (MPPT).

I.INTRODUCTION

Globalization and inter-countries energy sharing are considered as the conceivable future for the globe. In the present time, a significant proportion of the world's population is still living in remote rural areas with almost no access to electricity. Around 17 % of the world population (1.2 billion) cannot use electricity [1] and almost 80 % are living in rural spots [2]. Meanwhile, about 2 billion population around the globe have no access to grid-based electricity according to the most recent statistics [3]. Mostly, these peoples live in remote areas with no access to the national grid. According to [1], biomass is being used by around 3 billion worldwide habitats
for cooking, heating and lighting purpose and resulted in 3.1 million premature deaths due to air pollution with incomplete biomass combustion. This is highlighted as the main reason for cramping the economic and social development of such communities in developing countries like Pakistan.

Moreover, greenhouse gas (GHG) emissions are produced from many sources as shown in Fig. 1 in which it is noted that the dominant sector of producing these emissions is the energy sector through the conventional ways of energy production, while residential buildings indirectly produce the largest proportion of CO2 [4].

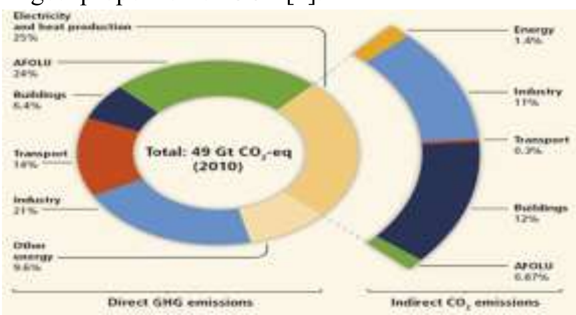

FIGURE 1. Sources of CO2 by economic sector [5].

Conventional energy sources (CESs) cannot meet the day after day growth in energy demand due to their expensive capital cost, limitations of its fuel and the in feasibility of grid extensions due to geographical locations. Furthermore, as mentioned, CESs are the major contributor to greenhouse gas (GHG) emissions and the most severe threat to the environment and human health. Due to what has been mentioned, establishing small-scale grids (micro grids) is considered a shining solution to face most of the above-mentioned obstacles. Renewable energy resources (RERs) are the more feasible option to tackle all modern global warming and depleting fuel issues. These RERs (e.g. PV, wind turbines, fuel cells) can be easily integrated with each other in different micro grid (MG) configurations for electrification of remote and urban areas. The various hybrid configurations of RERs are adopted in literature and are considered as the most cost-effective, and environmentally friendly. However, its intermittent nature is considered as the main drawback which needs to be handled carefully with coefficient energy management and control (EMCS) algorithms. Among the different control techniques that can be used to achieve the EMCS, Model Predictive Control (MPC) is utilized because of the reason that this algorithm is mainly classified's as one of the most powerful artificiality intelligence and non-linear programming approaches.

Due to the merits of MPC in addressing the systematic processing of constrained multi variable, it is well developed to handle the issues of power systems and power plants [6]. Hierarchical and distributed MPC is more efficient for handling large and complex power system problems through future prediction of control actions. Finite control set MPC (FCS-MPC) is the most frequently used among MPC controls due to its simplicity and high accuracy [7].

MPC is used in various applications including load frequency control for dynamic performance improvement under various disturbances and many applications in electrical drives(speed/position/torque control, torque ripple reduction, control) [8]. VSI with LC is widely used in power supplies for high-quality output, which is also the future application in an embedded network of electrical aircraft [9]. Currently, renewable energy share worldwide is only 11 % while it is expected to increase by 60 % in 2070. The global capacity of wind and solar photovoltaic (PV) is increased to 514.8 GW and 399.6 GW respectively [6]. Fig. 2 shows the global trend for investment in the renewable energy sector. About the GCC countries [10], RERs penetration into the existing grid is an economically viable option for diversifying electricity mix and creating an avenue. Multi directional power with a wide distribution system is the possible future of power grids in GCC states. Solar energy is going to be more competitive in all GCC regions and hence private would play their role in this regard. Proper deployment of new technologies (i.e. smart grid and smart cities) would be the economic growth factor with more revenue as well as the political stability of GCC countries with neighbors. The most feasible GCC regions for technology implementation are UAE, KSA, and Kuwait [10]. Pakistan is facing a severe problem of energy shortage and this shortfall is increasing with each passing day. Over 51 million peoples in Pakistan are still living with off-grid access to electricity [11]. nine cities with consideration family members in one household [13]. In Pakistan, key points of national power policy 2013 include load shedding elimination, decreasing transmission and distribution losses from 23 25 % to 16 %, increasing revenue from 85 % to 95 % and time reduction for decision making. Power policy 2015 focused on private

II. RESEARCH BACKGROUND SYNOPSIS

Several researchers emphasized the study of standalone HRES. Table 2. summarizes the addressed researches that investigated such kind of systems, such as the reconfiguration of the HRES, the applied algorithms as well as the main objectives are presented. Table 3 shows a comprehensive study of the research methodologies of the literature in terms of their contribution and drawbacks. According to the performance rating for the suggested energy management and control of HRES, a comparison between suggested work and presented literature is shown in Table 4. Results show that most of the literature investigated PI-based control but thorough investigation on the basis of design optimization is not presented. The wind control unit in the current study includes an uncontrolled rectifier which is simple, and economical. Moreover, an uncontrolled rectifier works without IGBTs and there is no need for additional controllers for control signals and thereby reducing the complexity and system cost. Most of the published literature was not thoroughly analyzed by considering wind and PV MPPT, uncontrolled wind rectifier, battery controller for regulating dc voltage, THD analysis, comparison of PI and FCS-MPVC for inverter control. Most of the addressed literature studies have been solely concentrated on either design optimization of HRES or energy management system (EMS). In this work, the optimal design of HRES with the most suitable and advanced EMS approach is proposed. First, the detailed techno economic analysis with multiple hybrid scenarios for diesel, solar photovoltaic (PV), wind, battery, and converter are applied for the design optimization of HRES. The developed model is then utilized to the load demand of an islander domestic area sited in Pakistan with the consideration of real demand and weather information. Second, MATLAB/Simulation R is used to develop a self-made simulation tool for the implementation of the suggested EMS. The optimized model is tested on the proposed EMS and the performance of the suggested model is improved for power quality, steady-state and transient stability with intermittent generation and nonfluctuating load demand. Summarized points from the comprehensive literature review are:

The HRES reconfiguration are considered to be the most reliable and economically viable options with minimum GHG emissions. While multiple for any resources data, and environmental conditions.

The major focus of the literature is either on optimal sizing with economically viable reconfiguration or on powermanagement of HRES. Both features are not given much attention at the same time. According to the best of authors' understanding, the proposed strategy by handling optimal design and power management simultaneously for the PV-WT-Battery system using FCS-MPC with reconfiguration inverter for a standalone HRES is not investigated in the literature.

Based on the above-mentioned circumstances, the objectives and scope of the presented work are summarized as follows:

To the drastic increase in electricity demand, the sample location of the Baluchistan province in Pakistan is investigated with the available energy resources including PV and wind. and generic methodology for optimization of components size with power control and energy management for off-grid HRES is presented. The proposed methodology is endorsed with a real domestic case study for electrification in Pakistan.

The optimal HRES scheme is obtained with the aid of feasibility study keeping in view the minimum cost and least emission. Minimum TNPC, LCOE, and improved model reliability are integrated as an objective function. HOMER R software is used for this purpose.Verification of a properly designed EMS is executed with the help of a self-made Simulink model in MATLAB R environment. The suggested EMS strategy is implemented with battery SOC to maintain load balance as well as dc bus voltage by keeping in view the battery SOC within the permissible limits, with maximum wind and PV power extraction while maintaining the ac bus voltage constant under nonfluctuating loads, and source disturbances (wind speed and solar irradiance). MPC is the most preferable solution for complex control problems [55]. The advantages of the suggested FCS-MPC based model are listed as follows:

The significant advantage of MPC management is simplicity while the concepts are very heuristic and intuitive in nature and easily understandable. The suggested MPC based EMS model is more proper for multi-variable systems and can be extended accordingly. The suggested EMS model is applicable for real on-line systems of non-linear nature.

The proposed FCS-MPC methodology with a complete solution for optimal design with energy management and control for the proposed domestic site is not analyzed in the literature.

The extension of the system with the proposed FCS-MPC controller is very easy ranging from domestic to commercial and agriculture loads. The proposed control strategy with FCS-MPC select the optimal strategy by controlling the interaction and constraints among different variables. Therefore, this strategy serves the purpose of economic benefactress with the quick operation and predicts the dynamic behavior for linear as well as non-linear multi variable models.

1 As compared to most widely used PI control, the suggested MPC based model can also be applied for grid connected applications in addition to standalone systems during transient stability analysis.

2The settlement time for FCS-MPC control is less and is applied to minimize the errors and eliminate signal harmonics from the output voltage/current.

3 The proposed control methodology does not need any modulation scheme and is applicable for variable switching frequency.

4 The steady-state performance is better for all three reference frames with low design complexity and easy implementation of the resulting FCS-MPC controller in experimental studies.

5 The current model based on PV-WT-DG-battery converter is the improvement of the WT-DG-battery converter model of

2) PV GENERATOR

The solar power is comparatively cheap as compared to wind power because of no wear and tear [6]. Incremental

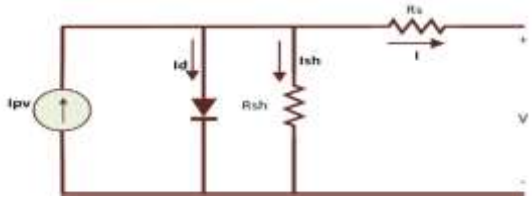

FIGURE 12. Equivalent circuit of single PV cell.

conductance (IC) is a commonly used method for solar PV MPPT which improves steady-state as well as dynamic response with good performance under fast-changing atmospheric conditions. Its basic principle for three MPP tracking conditions states that the power derivative is zero at MPP while it is negative on the right side of MPP and positive on the left side for power versus voltage curve. It can be expressed as [65].

IV. OPTIMAL SIZING AND ECONOMIC ANALYSIS USING HOMER PRO

Different optimization tools compared in [73], are discussed and used in literature to design an optimally planned HRES. Out of 41 software tools the most frequently used and highly recommended in various research studies. HOMER is a robust techno-economic optimization tool [45] which allows adaptability to analyze and simulate techno-economic models and design optimization of HRES units [45]. Its optimization algorithms allow the designer as well as the decision-makers to estimate the feasibility in terms of economic and technical aspects with various technical selections regarding the continuations in technology costs as well as the availability of resources. Hence, HOMER is selected for techno-economic analysis to determine the most suitable model choice for fulfilling the load demand of the suggested location. HOMER evaluates quickly and easily for feasible and optimal plans out of various possible solutions. The proposed optimization ow chart is shown in Fig. 13. HOMER optimizes the sizes of PV panels, the number of wind turbine units, the number of battery storage units, and the a number of converters [2]. HOMER optimization is based on the

input parameters including load demand, energy resources data, economic and technical aspects of each component, design constraints, proposed management, and control strategy, emission data [2], [45] with total NPC as the objective function of optimization strategy [45]. HOMER analysis is based on one-year optimization for the evaluation of technical, environmental, and economic aspects of HRES [80].

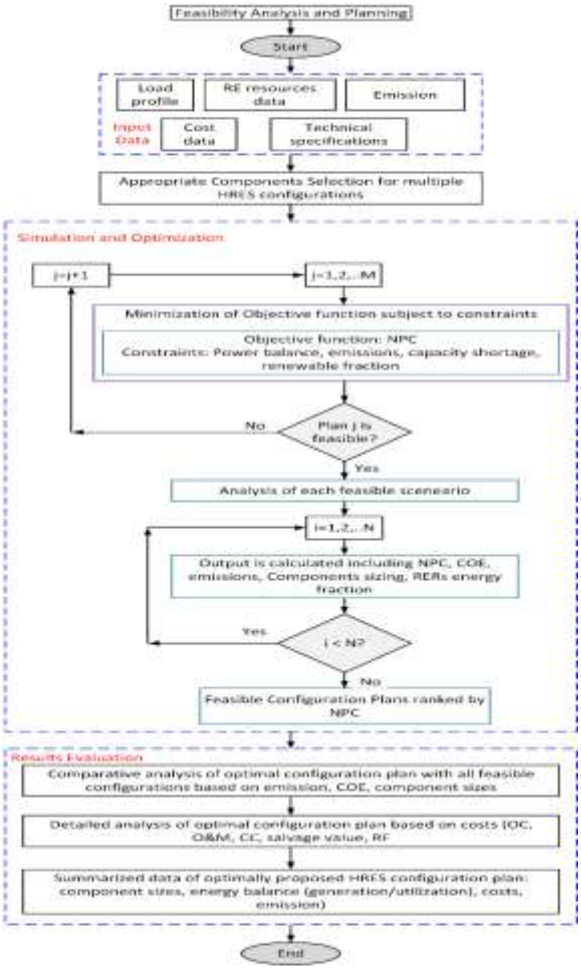

FIGURE 13. Implemented methodology for HRES design optimization.

Afterward, extrapolation of all costs works for the rest of the years throughout the project lifetime, which is established on linear depreciation and the most feasible plans to guarantee uninterruptible power supply and energy demand balance based on hourly duration [45]. After completing the testing step for all potential plans of HRES, the feasible reconfiguration are found and graded on the basis of design objectives

V. TECHNICAL ANALYSIS USING MATLAB

A. FCS-MPC FOR RECONFIGURABLE INVERTER

Finite control set MPC is suggested for dc-ac interlinking converter control for regulation of load voltage magnitude. FCS-MPC for two-level three-leg voltage source inverters is analyzed in this paper. The presented control scheme selects the most optimal state out of all seven possible switching FIGURE 14. Applied FCS-MPC control for a re configurable inverter of HMG. states to minimize the cost function. Simulation studies of MPC based control scheme show compensation of perturbation in load, source and parameters with output voltage is continuously tracking the reference value without normal inverter operation. A dc-dc battery converter is applied to regulate the dc voltage. PV and wind converters are applied for extracting maximum power from PV and wind units. Step by step control and management strategies are discussed in detail in the following section.

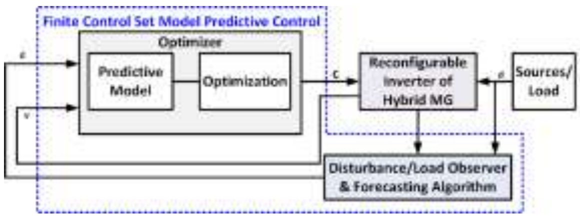

Fig. 14 shows the concept of the MPC control strategy. the variables which are needed to handle and solve the speciousness problem are represented by v.

The disturbance is represented with d. the control variable is expressed by c. w is the forecaster value of the processed variable. Based on the measurements

of the present system (v) and disturbances/forecaster

values (d), the optimizer can be simulated. FCS-MPC scheme is applied for primary control of the interlining voltage source inverter, including power droop control, reference generator (three-phase), and inner control loop. In contrast to conventional controllers, FCS-MPC has no requirement of PI controllers to implement the inner current and outer voltage control loop or any other complex modulation steps (like PWM and SVPWM) while this online optimization scheme is quite simple and intuitive with the fast-dynamic response as compared to the traditional control schemes. The working principle of the FCS-MPVC control mechanism is discussed in the sections below.

In the step, Clark transformation is applied to convert

voltage signals from reference, which are the inputs for the inner loop. Measurement of RLC

used to generate the switching signals for interlining VSI. The measurements of RLC which are taken from primary control are then used to calculate instantaneous powers (P and Q) while fundamental powers are also calculated. Droop control strategy with P□V and Q□! is implemented for regulating the ac bus voltage. Reference signals for VSI transistors (MOSFETs) are generated by using a three-phase sinusoidal generator to regulate the voltage.

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Discrete-time state-space modeling is implemented with the help of RLC parameters. FCS-MPVC based algorithm is used to predict voltage values for all fourteen (14) combinations for the next sampling duration. The continuous state-space (CSS) model is designed in the discrete-time state-space (DSS) model. MPC algorithm predicts voltage vectors for all possible combinations for the

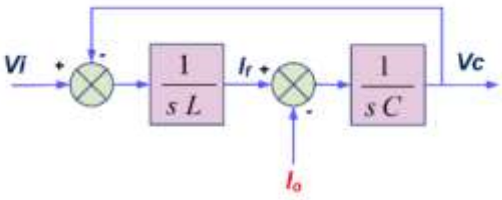


FIGURE 15. Filter model for Predictive voltage control.

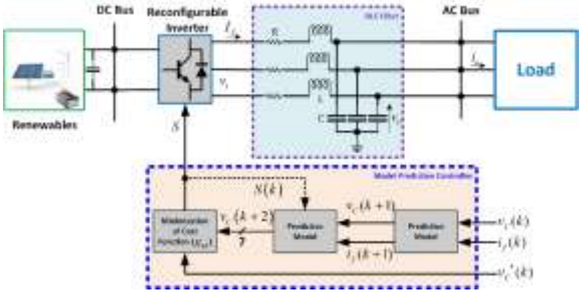


FIGURE 16. FCS-MPC scheme for interlinking converter.

next sampling time. CSS and DSS models, input voltage vector, and objective functions are expressed in [42]. Seven switching states are tested to the most optimal voltage vector and its corresponding signals for the IGBT switches of VSI. The model (see Fig. 15) for Predictive voltage control of Fig.16 is

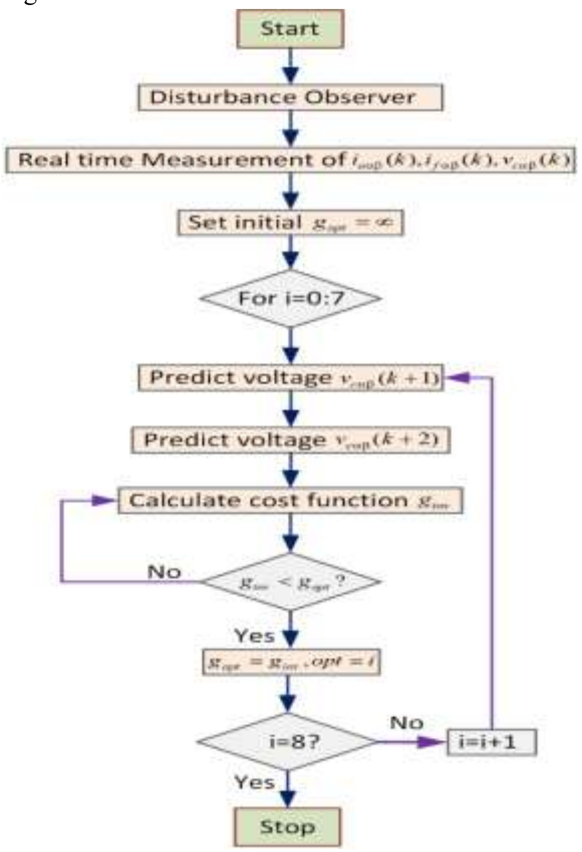
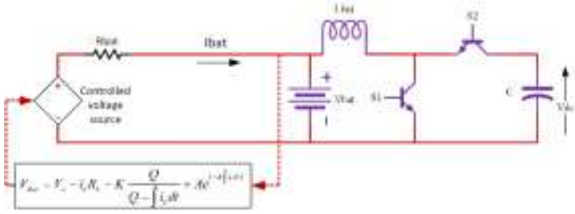


FIGURE 17. The flow chart of the implemented FCS-MPC algorithm. The load observer is suggested with the following cost



function,FIGURE 18. Battery model.

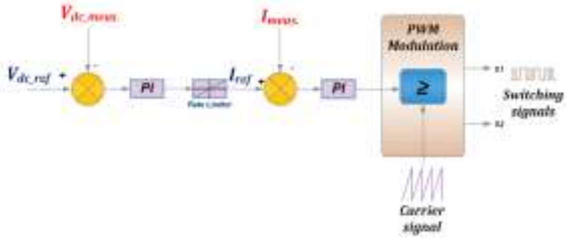


FIGURE 19. A buck-boost converter control.

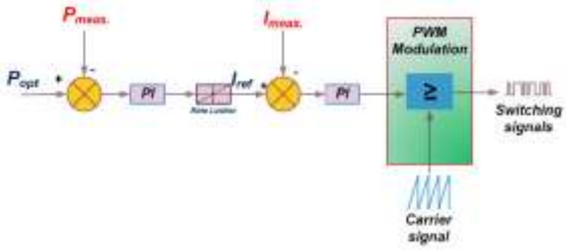


FIGURE 20. The boost converter control for wind MPPT.

where Pmax and Qmax are the maximum powers supplied by the inverter. 1! and 1V are maximum deviations of frequency and voltage amplitude of the inverter output. The values of m and n are 0.0014 and 0.0008 respectively.

B. BUCK-BOOST BATTERY CONTROLLER

For the regulation of dc bus voltage, Fig. 18 shows the battery model while Fig. 19 shows the control of a buck-boost converter, which comprises current and voltage regulators. The SOC is controlled from being discharged below 20 % and overcharged above 70 %. The net power is the summation of generated power from PV, WT, The battery SOC management scheme along with the applied dispatch strategy is demonstrated in Fig 22. Fig 26 presents the complete Simulation model of the most optimal HRES with PV-wind-battery units.

C. BOOST CONVERTER CONTROL

Wind generator with a pitch angle (i.e. zero) and variable speed is used, while the PMSG parameters and WT parameters are taken from [42]. Fig.20 shows the MPPT control for the boost converter.

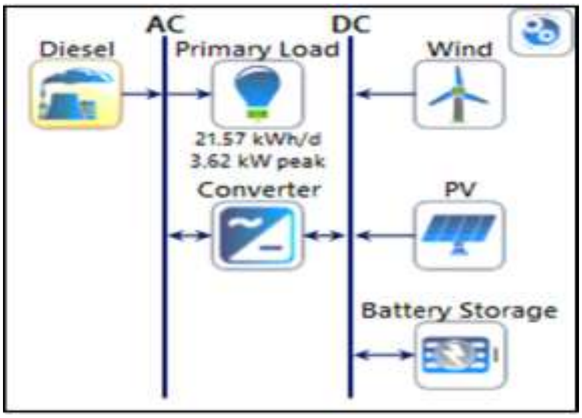


FIGURE 21. HOMER model for the proposed HRES.

III.RESULTS OF SIMULATION

B. PERFORMANCE ANALYSIS OF PROPOSED ENERGY MANAGEMENT AND CONTROL SCHEME

An energy management and control schemes are implemented based on the FCS-MPC model keeping in view the uctuating load demands and intermittent renewable generation as shown in Figure 26. The parameters of PI controllers are shown in Table 8, while Table 9 shows the ratings of PV, wind and RLC

1) MPC CONTROL WITH SOC UPPER LIMIT USING PV-MPPT

Fig. 26 is analyzed to check the operation of the suggested model. Variable wind speed changing from 7.45 m/s (at 5 s) to 6.95 m/s (at 13s) is applied (see Fig. 27), while variable PV irradiance from 980 kWh/m2 (at 5 s) to 1200 kWh/m2 (at 16 s) is applied. During wind speed variation at 13s, the power coefficient curve shows a slightly spike from its normal value of 0.48 which is negligible.

The regulated power coefficient which exactly follows the reference value shows coefficient and intelligent design and performance of the MPPT wind controller through a dc-dc converter. The maximum value of 0.48 is achieved at a tip speed ratio with a value of 8 as shown in Fig. 28 (a). Fig. 28 (b) shows the dc bus voltage which is controlled by applying a dc-dc battery converter to stabilize the voltage at a constant dc voltage of 750 V. Based on the energy

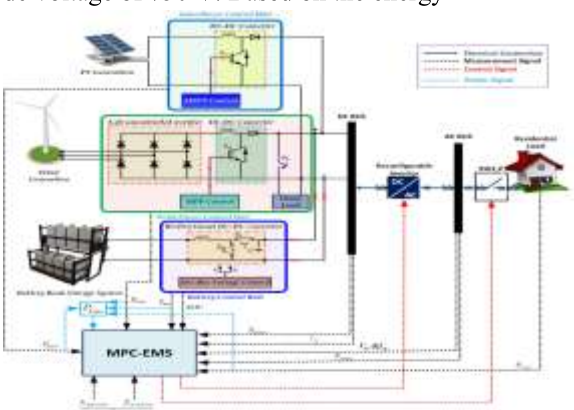


FIGURE 26. The control scheme of an optimal PV-Wind-battery HRES.

interlinking converter effectively regulated the three-phase load voltage during external load disturbance.

2) MPC CONTROL WITH SOC LOWER LIMIT USING PV-MPPT

Fig. 20 is analyzed to check the operation of the suggested model. To elaborate on the operating principle of EMS with a lower SOC limit, battery SOC is kept below 20 %. Critical load i.e. the main load is ON while non-critical loads (i.e. primary and secondary) are both OFF as shown in Figs. 33. Fig. 31 shows the power-sharing among PV, wind, load, and battery and dc bus voltage. During the start of simulation at 5 s when both PV and wind are integrated for power-sharing, ripples in PV power dc bus voltage are observed. The possible reason for these ripples is the minimum load requirement while the MPPT controller performance is not satisfactory which contributes ripples to PV power and ultimately dc bus voltage is also disturbed. The other possible reasons and its remedy may be explored in future research. At 7.595 s, battery SOC reaches a minimum set limit of 20%and EMS enabled switch-1 to ON position to inject primary load into the system which can be seen from Fig. 31, Fig. 32, and Fig. 33 by observing load power, load current, and load switch-1 respectively. A dc bus voltage remained constant during this load disturbance. At 13 s, wind power is reduced while battery charging power is also decreased tothis energy gap.

Fig. 32 shows the regulated and pure sinusoidal waveform which validates the robust performance of the FCS-MPVC strategy. Secondary load remained OFF throughout the simulation because of the SOC value below its upper limit of 70 %. At 16 s, excess power generated due to the power from PV is absorbed by the battery to maintain the constant load demand and wind power generation. A dc voltage is slightly increased due to high power injection from the PV generator.

3) PI CONTROL WITH SOC UPPER LIMIT USING PV-MPPT

Fig. 20 is analyzed to check the operation of the suggested model with PI control. The PV-wind-battery model is simulated with the implementation of the PV-MPPT algorithm

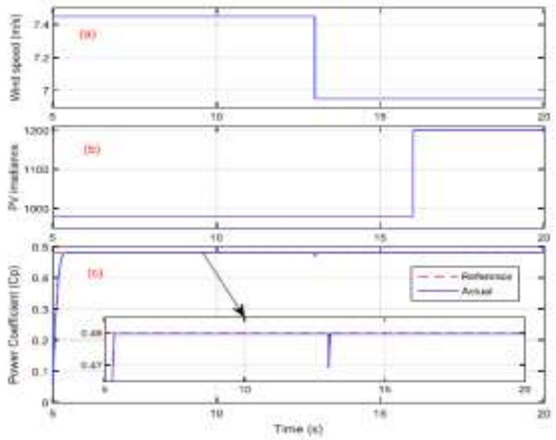


FIGURE 27. Input indicators of PV and WT (a) Variable wind speed (b) Variable PV irradiance (c) Power coefficient.

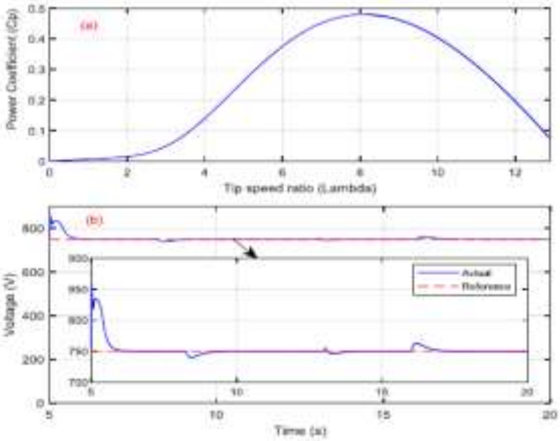


FIGURE 28. WT indicator and dc bus voltage (a) Tip speed ratio against power coefficient (b) A dc voltage regulation by using a buck-boost controller.

by using the PI control strategy. The model is analyzed for the upper SOC limit of the battery. Fig. 34 shows a three phase load current and voltage. Power- exchange among PV, wind, battery, and load is shown in Fig. 35. At 8.869 s, battery SOC reaches 70 % (i.e. upper limit) while suggested EMS

strategy switched ON the secondary load. The three-phase current and voltage wave forms have different peaks for each phase. Further, more load power ripples are observed in the case of PI control.

4) PI CONTROL WITH SOC LOWER LIMIT USING PV-MPPT

To check the performance of the suggested model with PI control, the PV-wind-battery model is simulated with the implementation of the PV-MPPT algorithm by using the PI control strategy. The model is analyzed for the lower SOC limit of the battery. Fig. 36 shows a three-phase load current

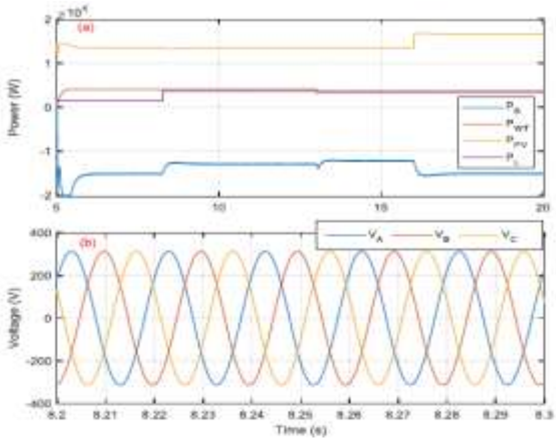


FIGURE 29. Performance analysis of output power and voltage using FCS-MPC method with upper SOC limit and PV MPPT (a) Power-balance among PV, wind, battery, and load (b) Three-phase ac load voltage.

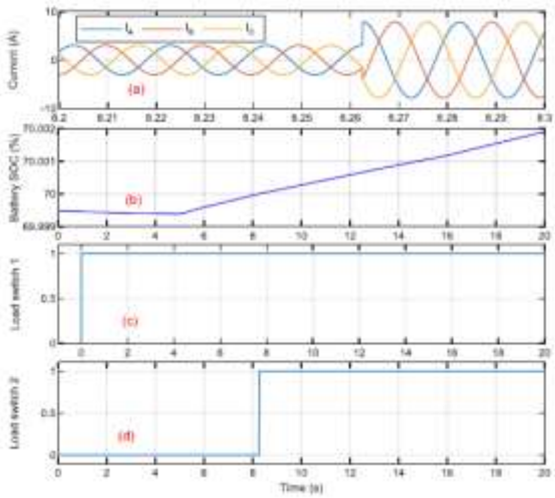


FIGURE 30. Parameters of Load fluctuation with battery SOC using FCS-MPC method with upper SOC limit and PV MPPT (a) Three-phase ac current (b) Battery SOC during charging mode (c) Load switch-1 for primary load control (d) Load switch-2 for secondary load control.

and the three-phase ac voltage. Power- exchange among PV, wind, battery, and load is shown in Fig 37. At 8.155 s, battery SOC reaches 20 % (i.e. lower SOC limit) as shown in Fig 37 while suggested EMS strategy switched ON the secondary load. The three-phase current and voltage waveform have different peaks for each phase. Further, more load power ripples are again observed in the case of PI control.

5) MPC CONTROL WITHOUT PV-MPPT

To check the operation of the suggested model without PV-MPPT, the PV-wind-battery model is simulated without implementing the PV-MPPT algorithm for performance comparison of both models by using FCS-MPVC strategy

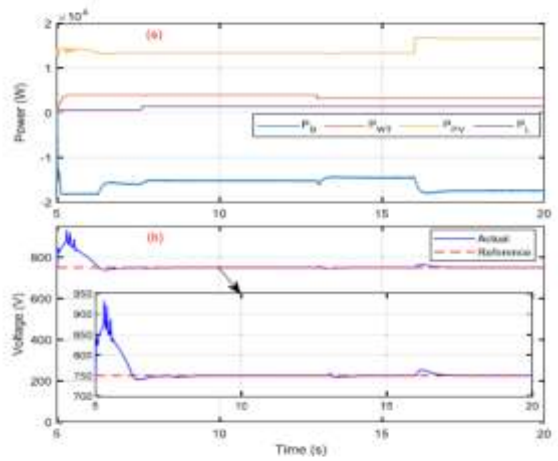


FIGURE 31. Performance analysis of power and dc voltage using FCS-MPC method with lower SOC limit and PV MPPT (a) Power- exchange among PV, wind, battery, and load (b) A dc voltage at variable wind speed.

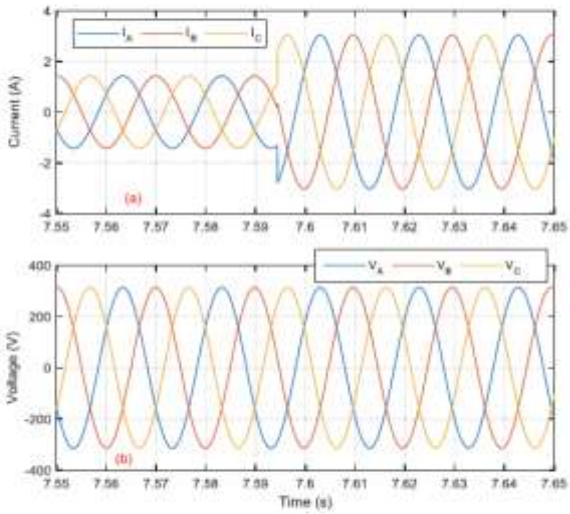


FIGURE 32. Output load signals using FCS-MPC method with lower SOC limit and PV MPPT (a) Three-phase current (b) Three-phase voltage. PV panel is connected with the rest of the HRES through the capacitor link. PV temperature is constant at 25 (see Fig. 38) while PV irradiance is changed from 1000 kWh/m2 (at 5 s) into 950 kWh/m2 (at 16 s). Wind speed is set at 8.8 m/s at 5 s and decreased to 8.3 m/s at 13 s. A dc voltage is seen to be more stable as shown in Fig. 39 despite the fact that uncontrolled PV generation has variable although stable power. At 9.71 s, battery SOC crosses the upper limit of 70% (see Fig. 40) and hence the EMS enabled switch-2 to feed the secondary load which can be observed from the load power signal of Fig. 39 and three-phase load current curve of Fig. 40. Fig. 40 (b) shows the regulated ac load voltage under the FCSMPVC control strategy.It is observed from Fig. 39 that the variation of wind and load has a direct impact on PV generation fluctuation.

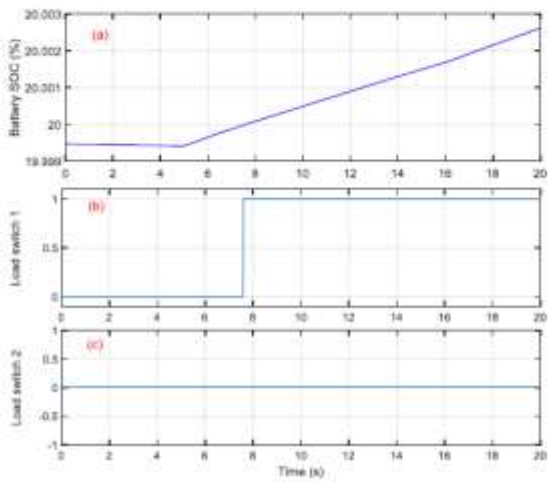


FIGURE 33. Analysis of battery SOC with load management using FCS-MPC method with lower SOC limit and PV MPPT (a) Battery SOC lower limit during charging mode (b) Load switch-1 for primary load control (c) Load switch-2 for secondary load control.

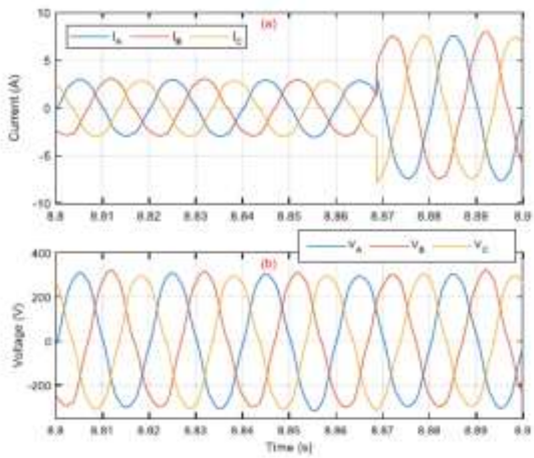


FIGURE 34. Output signals during PI control method with upper SOC limit and PV MPPT (a) Three-phase ac current (b)Three- phase ac voltage. This effect of PV fluctuation is observed at 9.71 s when the secondary load is switched ON. The second effect is observed at 13 s when wind generation capacity is reduced by reducing the wind speed, while the last impact is seen at 16 s when PV power itself is decreased by reducing the PV irradiance.

6) PI CONTROL WITHOUT PV-MPPT

To check the performance of the suggested model with PI control, the PV-wind-battery model is simulated without implementing the PV-MPPT algorithm by using the PI control strategy. Fig. 41 shows a three-phase load current and the three-phase ac voltage. Power- exchange among PV, wind, battery, and load is shown in Fig. 42. At 9.866 s, battery SOC reaches 70 % (i.e. upper limit) as shown in Fig 42 while EMS activates the secondary load. The three-phase current and voltage wave forms have different peaks for each phase.

V.CONCLUSION

Standalone HRES with PV-wind-battery is proposed as the optimal and economically most viable system, as determined by techno-economic studies carried out through HOMER and MATLAB along with FCS-MPC of a reconfiguration inverter, to the residential electricity requirement of Sherani district in the Province of Baluchistan, Pakistan. Firstly, optimal sizing of HRES components and economic investigation is performed through HOMER, while simulation studies for the suggested area with practical and real data of load as well as weather is investigated using different costs (capital, replacement, O&M), operating life, and constituencies of HRES components, project
lifetime, meteorological data assessment, and interest rate as the input parameters; load demand, resources availability, operating reserves, allowable capacity shortage, GHG emission penalties as optimization constraints; and NPC as decision variable. Out of nine possible optimal con-configurations namely PV-wind-battery, PV-wind-diesel-battery, PV-battery, PV-diesel-battery, wind-diesel-battery, PV-wind diesel, PV-diesel, wind-diesel, and diesel-battery, as examined during this work, PV-wind-battery is obtained as the
most feasible and economically viable reconfiguration (i.e. winning plan) with minimum NPC ($ 28,620) and COE ($ 0.311/kWh) which shows 81.65 % reduction in cost and 100% preserving in toxic emission, while fulfilling 100 % energy demand with 67.3 % of excess energy. The proposed optimal HRES design (winning plan) comprises 13.4 kW PV, 4 kW wind, 3.88 kW converter, and 20 units of 2.37 kWh lead-acid battery. Optimal sizes of HRES components are then used to design a management and control strategy in ATLAB/Simulation with control set model predictive control (FCS-MPC) of reconfiguration inverter for technical analysis based on power balance between HRES elements, constant dc and ac voltages, safe operating range of battery SOC, coefficient
ac voltage quality, during variations of PV irradiance, wind speed, as well as load demand. The results are validated through simulations with total harmonic distortion (THD) of 0.30 % which is well below the allowable limit according to IEEE-929 and IEEE-519 standards as compared to 5.44 %
THD with the conventional PI control scheme.

The presented scheme would be an assessing tool for the governments, energy sector/micro grid planners, model designers, and researchers to investigate suitable policies, mechanisms, effective and coefficient design of HRESs. An increasing, unpredictable and abrupt load demand of the society can be handled by integrating more renewable
generation in terms of a reliable, economical, and
environment-friendly scenarios with an understanding of intermittent generation The future work includes microgrid reconfiguration under inverter and rectification mode to control the voltage and frequency during the standalone mode, and power during the grid-connected mode.

VI.REFERENCES

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