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Design Methodology of Microcontroller Based Load Balancing and Synchronization

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ABSTRACT

Distributed power generation is one of the key research areas around the globe. Technically a lot of effort is required to make two independent distribute sources capable of driving common load in the same system. This paper presents a novel technique for inculcating two power sources in a system which drives the common load. Areal time switching methodology is proposed which makes the decision based upon the load statistics and then triggers the supporting source. Technique employs the inverters which converts the DC inputs from two distributed sources to AC output of same rating. Real time monitoring is conducted using microcontroller, which takes the feedback from current transformer (CT) and switches the supporting source when load exceeds the specified threshold range. Under such circumstances synchronized output from both the sources is used to drive the common load. However, under normal condition, it is also possible to store the extra power and can be used later on when needed. Simulation models of AC to DC converter, Inverter and switching circuitry are presented in this paper. The obtained result clearly demonstrates the effectiveness of proposed methodology.

Keywords: *CT, Inverter, Synchronization, Load Balancing, Microcontroller.*

1. INTRODUCTION

Recently the entire world is facing a great problem related to an increase in load and a constant power generation [1]. This makes one to realize that if load is increasing rapidly and power generation is constant then it is not possible for the system to drive the future needs. For this reason distributed power generations is receiving an attention of the researchers around the globe to be used in remote and rural areas [1].

It is challenging to synchronize two independent sources for example If one of the sources is providing AC power (e.g. Hydral Power Plant) while other is providing DC power (e.g. Solar panel).In order to make use of two sources to drive a load on common line, it is very important to have the real time monitoring circuitry which should turn on the supporting or extra source when load exceeds certain range.

The power from standby or supporting source can be stored by using a battery during low demand condition. This is referred as load balancing or load matching which can be defined as 'daily peak demand backup/reserve'. Similarly in order to utilize power of two sources at a time, it is essential that two sources should be synchronized i.e. frequency and speed of two sources should match exactly [2].

This has been a key research area for many researchers throughout the world from many years. Like P. Biczel et al. worked on control unit for power sources and load [3]. Similarly B. Enayati et al, presented a model for control of power flow for autonomous micro grid operations [4]. Both of these approaches lack the possibility of driving two sources at a time. Similarly J. A. Lopes and A.Madureira, have designed a controller for micro grids having multi inverters [5]. They have assumed one of the inverters as master and other as slave inverter. Their model does not perform well when harmonics are present in signals.J. Liang and Q.Zhong also presented a control technique for voltage source inverters connected to micro-grid, but this requires information of impedance which degrades its reliability [6].Similarly Yong Xue presented a PWM strategy for single Phase grid, but more abrupt variation in different parameters limits the performance [7].All of these techniques do not comment on the hardware efficiency analysis. In our approach we have shown both simulation model and outputs from hardware. Solution is also cost effective as simple transformers and microcontroller is used.

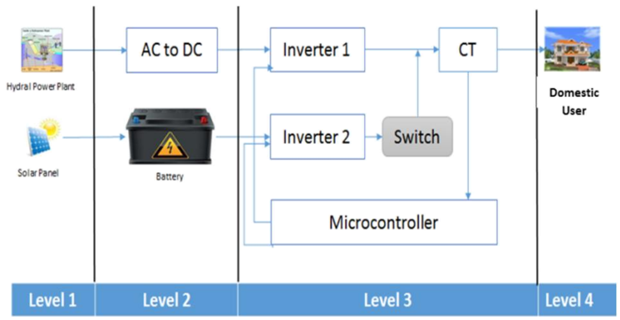

Fig. 1. Block Diagram of Proposed Model

2. PROPOSED METHODOLOGY

In proposed methodology for load sharing and synchronization the AC output from one of the sources is first converted to DC (and other source is providing the DC output in default), which will make both the outputs to be in DC. Afterwards both the outputs (DC) are fetched to inverter (PWM inverters), which in turn are connected to two power transformer of equal rating. This not only converts these DC inputs to AC , but they are designed in such way that both the outputs aresynchronized, making two sources suitable for driving the load on common line.
AC output will be driving the load under ordinary conditions under the threshold condition. Threshold condition is set at 90% of source 1 rating. Once load exceeds this range, a circuitry is required that should switch on the other sources whose output will be synchronized with output of alternative source. A CT cabbe used between Source with default AC output and load, which will feed its output to the Microcontroller. CT can accurately sense the current flow in the conductor [8]. Once the load on the line exceeds the 90% of transformer 1 (transformer fed by source 1), it is sensed by CT and subsequently the reading are fed to microcontroller, which switch on the other source (Transformer 2) and load is driven by two synchronized sources simultaneously. Block diagram of complete proposed model is presented Figure 1.Microcontroller programming flow graph is shown in Figure 2.

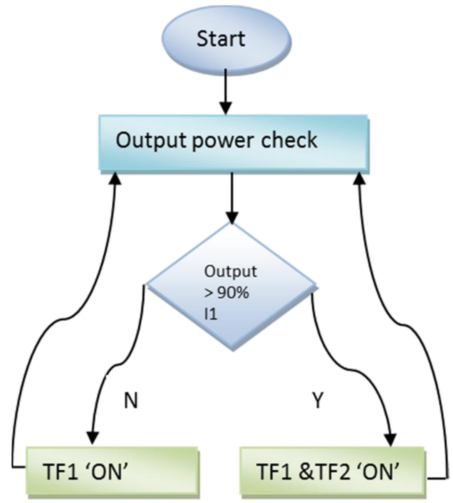

Fig. 2. Programming flow

3. MODULES DESIGN AND RESULT DISCUSSION

A. AC to DC converter

In order to convert the AC output of source 1 to DC, the default output is fed to step-down transformer. Specifically Centre tap transformer is used for conversion of 220V to 24V.Afterwards the output of step down transformer is given to bridge rectifier for full wave rectification. As $Vrms = 12V$, hence $Vm = \sqrt{2} \times Vrms$ $i.e$ 16.97v .Each diode in the rectifier can draw maximum of 1A and capacitors are used at the final output for obtaining a smooth waveform. Simulation model for AC to DC converter is shown in Figure 3.

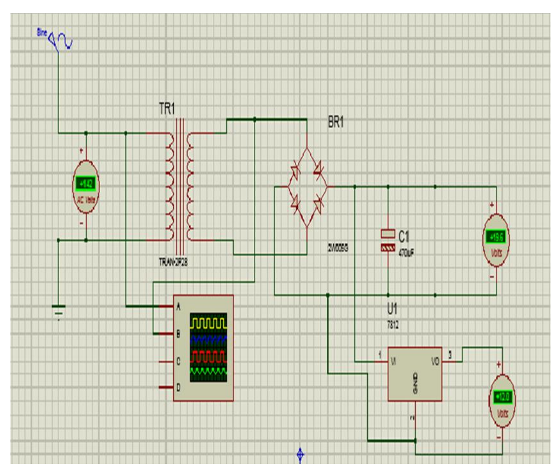

Fig. 3. Simulation Model for AC-DC Converter

Results of AC to DC converter are shown in Figure 4.Top most waveform (waveform A) is showing the default output from Source 1. The second waveform (Waveform B) is showing stepped down signal. Last two waveforms are showing the converted DC and default DC respectively.

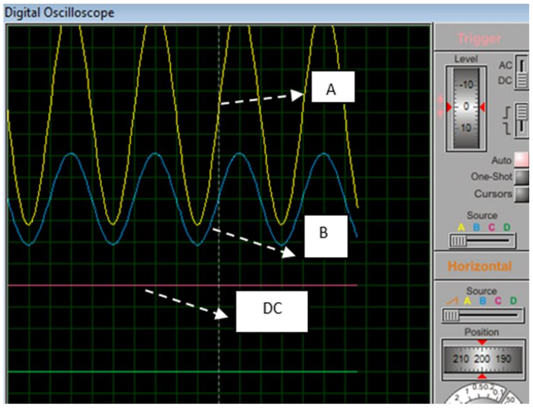

Fig. 4. AC-DC Converter Result

B. Inverter Design

Simulation model of inverter is shown in Figure 5.The inverters are controlled by microcontroller, which can easily be used to turn on or turn off any device like transistor and relays etc. (0V and 5V). But sometimes the voltage in-between the specified range is required for certain operations. For obtaining such sort of output from microcontroller chips, a special technique called Pulse width modulation (PWM) is used. More specifically this technique is employed to obtain an analogue signal from inherently digital devices like microcontroller. Recently most of the microcontrollers are equipped with a dedicated hardware for this purpose.

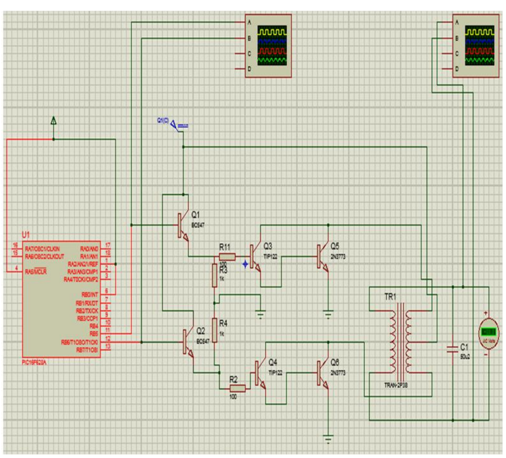

Fig. 5. Simulation model of Inverter

In design which is shown above, Pin 11 and P12 of port B of microcontroller is connected to transistors Q1 and Q2 respectively. For certain period of time (i.e. T*on*) there will be 5V at Pin 11 of microcontroller which will switch on the transistor and as result 12V will appear at the emitter of this particular transistor. Emitter of Q1 is then connected with base of Q3, but for safe operation of Q3 a voltage divider circuitry is used in between so that some voltage is dropped across R1 and a voltage of 1.2v appears at the base of transistor Q3. Similarly emitter of Q2 is connected with the base of Q4, and this circuit is used as a Darlington Pair.Darlington pair (DP) is normally a connection of two transistors such that current amplified by first one is in turn again amplified by second one in the connection [9]. Collectors of both Q2 and Q3 are connected to the input of transformer, showing that at 5v volts transformer will be in energizing state and at 0v it will be in de-energizing state.

Delays are taken in driving program, as above circuitry will be in operating state for positive half cycle, and below circuitry will work for negative half cycle. Capacitor is used at the output of transformer for smoothing the sinusoidal obtained.

PMV Inverter Calculations:

For the Inverters, Microcontroller will generate 50Hz frequency .it means the time period of the inverter will be 20msec, 10ms for positive and 10msec for negative half cycles. As for the positive half cycle:

T(positive)=10msec

If we take time period of 'T' for each PWM signal as 100µsec.So, then:

10msec=100µsec*(100 Cycles)

For 100µsec the frequency will be equal to

f=1/T= (1/100µsec)

f=10MHz

As Duty Cycle is 25% of Time period; So 10MHz/4=2.5MHz

From above value of frequency we can find out the value for the time for each Microcontroller.

T=1/2.5MHz=0.4µsec

As we want to obtain Sine Wave at the Output so it should be some function of Sin

Y=Sin (angle)

As for positive value of Sin wave the Y values are in between 0 to 1 and then 1 to 0.

If we want to check PWM width for Ton and Toff for the point y=0.5 at angle of 30 degree

T*on*=Y * S (Set Point)

Set point S=250

<u>Case 1:</u>

Y=0.5

T*on*=0.5*250=125

As for each Microcontroller instruction we need 0.4 µsec. So

T*on* =125*0.4µsec=50usec

T*off*=T-Ton

T*off*=100-50=50µsec

Case 2:

As for Y=0.866
$T_{on}=0.866*250$
$T_{on}=216.5$
As for each Microcontroller instruction we need 0.4 µsec
So
$T_{on}=216.5*0.4\mu sec=86.6\mu sec$
$T_{off}=T-T_{off}$
$=100-86.6=13.44\mu sec$

C. Hardware

Hardware based upon the proposed methodology is Figure 6. Cost of complete hardware based upon proposed technique is about USD 170. Efficiency of system along with voltage and current statistics with different load conditions is discussed in next section.

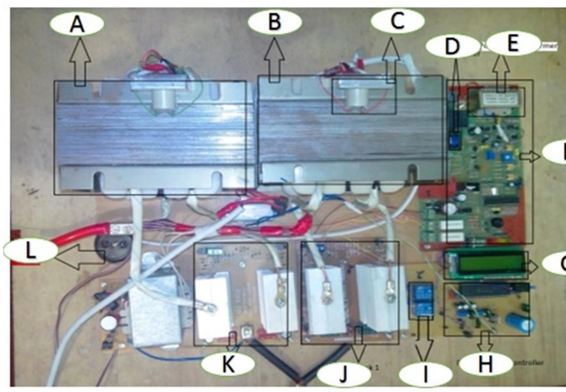

Fig. 6. Hardware of Proposed Model
Note: A: Transformer 1,B: Transformer 2, C: Voltmeter ,D:CT, E:PT ,F: Control circuitry, G:LCD, H: Microcontroller, I: Relay, J: MOSFET Bank 1, K: MOSFET Bank 2, L: Output

Synchronized output from hardware based upon proposed methodology is shown in Figure 7.This waveform shows the output of inverter 1 when there is no load. This output is used to drive the load, which is shown Figure 8.This is the condition when load is in specified range of inverter 1 (< 90% of specified range). When load increases the specified range inverter 2 turns 'ON' and both the inverters which are exactly synchronized are used to drive the common load. The output waveform is shown in Figure 9.

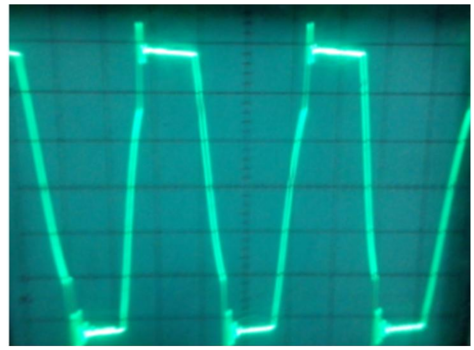

Fig. 7. Output of inverter 1 with no load

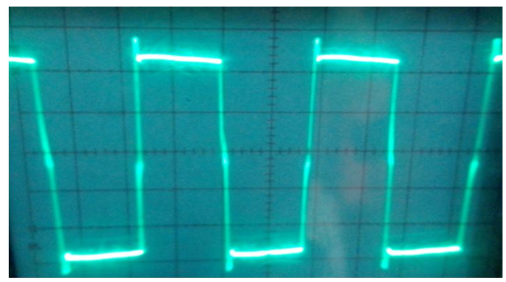

Fig. 8. Output of inverter 1 with load

It can be seen in the above waveforms that outputs of both inverter are exactly synchronized, making the two independent sources capable of driving the loads on the same line, which can surely have impact in many practical fields of operation. It should also be noted that these output waveforms are without use of LC filter, that's why the square waveforms are obtained. Complete sinusoidal waveforms are expected one LC filter will be used in model.

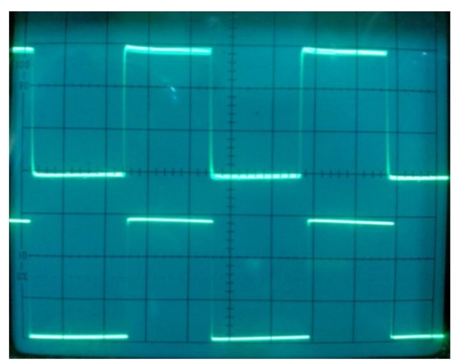

Fig. 9. synchronized output of 02 inverters

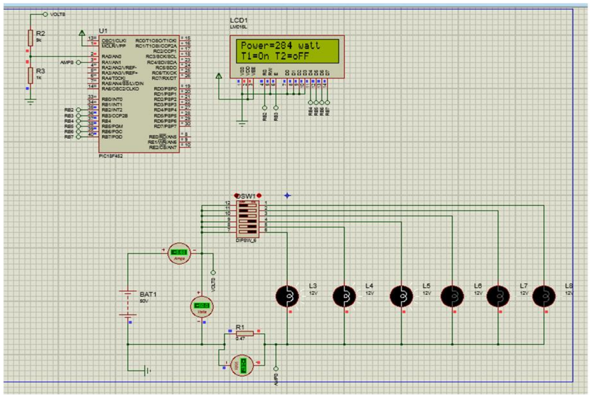

Fig. 10. Simulation Result Showing T1 on only

Both the inverters have transformers of equal rating at their final stage. These transformers are switched 'ON' and 'OFF' depending upon load statistic. When loadis below the rating of (below the 90% of specified range) transformer T1 is ON and T2 is 'OFF'. Switching statistics of 02 transformers is shown in Figures 10 & 11.

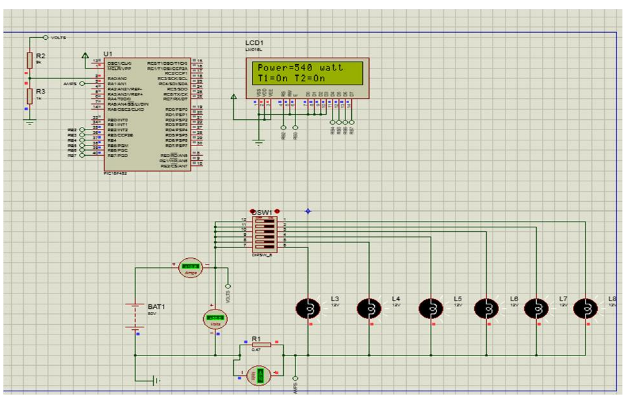

Fig. 11. Simulation Result Showing T1 & T2 both 'ON'

CT is used which constantly feeds the microcontroller with the statistics of load. Soon the load exceeds the specified range; CT feeds these statistics to microcontroller which in turns switch 'ON' the transformer T2 whose output is synchronized with output of source one. In this way it becomes possible to drive loads on same line.

When load is below the 90% of T1 rating, T2 is 'OFF', and load is driven by source 1 only. This is clearly shown in simulation as T1 is 'ON' and T2 is 'OFF'.Status of 02 inverters with different loads is shown below is tabular form. Efficiency of system along with output voltage and load current is also give in Table 1.

Table1: Inverters status with different loads

Load (W)	***Inv1***	***Inv 2***	***Input (V)***	***Output (V)***	***Eff= (Vo/Vin)*100***	***Curren t (A)***
200	ON	OFF	220v	215V	97%	0.93A
400	ON	OFF	220V	211V	96%	1.89A
600	ON	ON	220V	209V	95%	2.87A
720	ON	ON	220V	204V	92%	3.52A

4. SUMMARIZED CONCLUSIONS

Proposed work provides an efficient way for load sharing and synchronization at real time. This work not only focuses on scenarios where common load is driven by two synchronized sources , but source 2 can also feed the independent load until its power is not needed in conjunction with source 1 for driving the common load. Similarly it can also store energy when power requirements are on lower side.

Solution is also simple and cost effective as it is using simple microcontroller and industry standards CT for switching purposes. Complexity of the approach is also reduced by transforming both the outputs to DC and then two inverters of same capabilities are used for producing the synchronized outputs. The presented results clearly show the effectiveness of proposed methodology.This synchronization model is developed with the assumption that Source 1 should always be present, which means that proposed system will not work if Source 1 goes 'OFF'.

5. FUTURE WORK

In future the same work can also be extended by taking more than two sources into account. Moreover it is also a suggestion for future that synchronization may be done through control of firing angle and the cost and reliability of both systems may be investigated.

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